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1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS

REPORTS OF THE EXAMINERS

—OF—

SECTIONS V, VI & VIII.

(SECTION IV-B, OF THE CATALOGUE.)

ELECTRIC LAMPS.

CARBONS FOR ARC-LAMPS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, JUNE, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE
1885.

EDITING COMMITTEE.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTIONS V AND VIII.—ELECTRIC LAMPS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of Group B, Sections V and VIII, upon Electric Lamps.

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *May*, 1885.

Chairman Board of Examiners, International Electrical Exhibition:

DEAR SIR:—I herewith submit the report of "Group B" (Sections V and VIII) upon Electric Lamps. The observations on arc lamps were made, in the main, by Professors Brackett, Young, Geyer, and Anthony, Mr. Hering and Mr. Bussmann. Professors Cross and Mendenhall took part, when present. Occasional assistance was rendered by Lieut. Wyckoff, Lieut. Murdock, and Dr. Dudley. Mr. Eldridge assisted by recording the photometric observations.

The arduous labor of reducing the observations and verifying the results was almost wholly performed by Lieut. Murdock, Secretary of the Group, who deserves the hearty thanks of the other members of the committee for his patience and perseverance in this most uninteresting work.

Respectfully,

WM. A. ANTHONY,
Chairman of Group B.

ITHACA, N. Y., April 24, 1885.

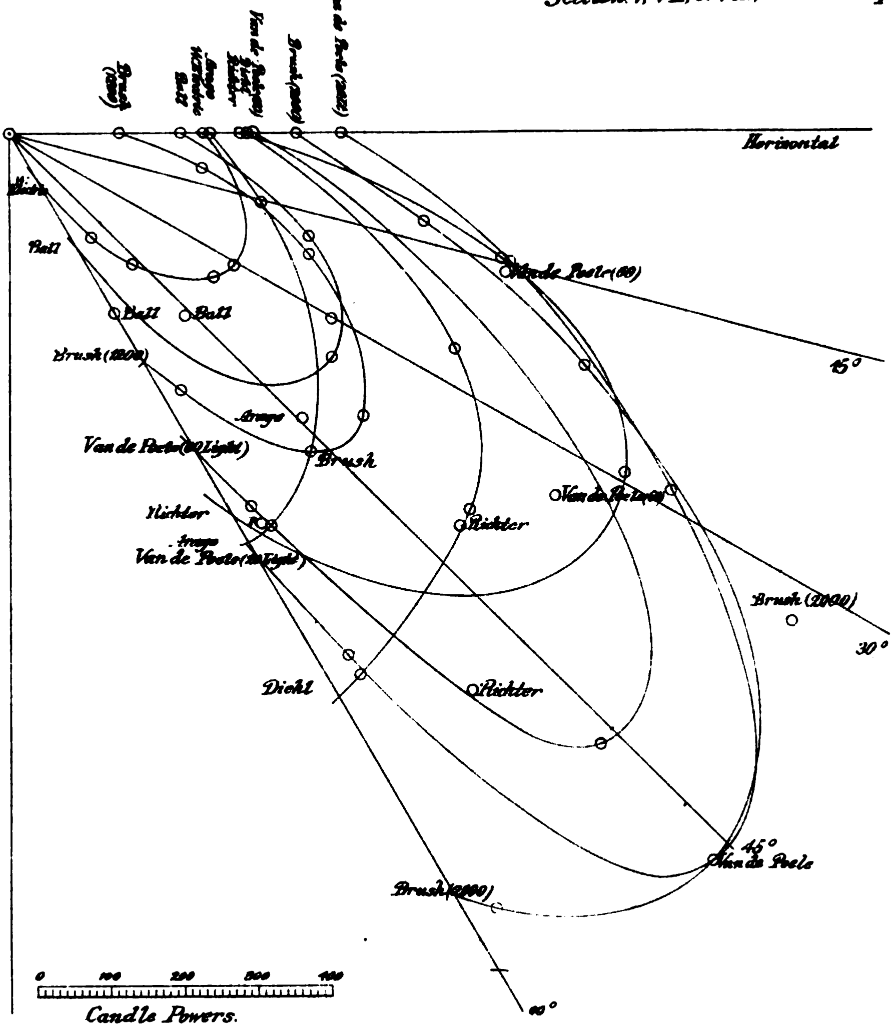
The original scheme of committee work divided observations of electric lamps among four different sections, known respectively as the sections on "Arc Lamps," "Carbons for Arc Lamps," "Incandescent Lamps." and "Photometric Measurements." As the membership of all these sections was the same, it was soon found that this subdivision entailed unnecessary work and needless discussion, and the four sections were therefore consolidated into a group, designated by the Executive Committee as "Group B."* The work of this group covered the whole subject of measurements on electric lamps.

It having been long recognized that observations on incandescent lamps by which the *efficiency* only was ascertained, were unsatisfactory, the desirability of observations to determine the *life* of lamps was obvious, and endeavors were made to organize such a test. The time required for such work prevented the Committee from carrying it out, but the Executive Committee of the exhibition having offered to arrange such a test, the question was considered by the members of Group B, and it was voted that the tests of incandescent lamps should include *duration*, as well as *efficiency* measurements, and that such tests should be carried out under the direction of the Executive Committee of the Franklin Institute for the Exhibition. It was further voted that "Group B" should co-operate in such tests so far as was possible. A duration test was arranged by the Executive Committee, and invitations to take part therein were extended to the various incandescent lamp companies represented in the exhibition. The work of "Group B" was therefore confined to observations of arc lamps.

The examinations of arc lamps consisted mainly in measurements of illuminating power at various angles, from a horizontal plane to sixty degrees below, and in measurements of current and potential at the terminals of the lamp. No attempt was made to examine critically the regulating mechanism, or to measure the resistances of the regulating coils. The examinations were all conducted at the "test-house." Each lamp was supplied with current from the machine for which it was especially designed, and was adjusted and put in operation by the exhibitor, who also regulated the strength of the current.

Currents and potentials were measured by the same instruments employed in measurements of machines. The photometric apparatus and

* It was afterwards found advisable to present the report of Section VI, (Carbons) separately from the rest, but it will be found herewith subjoined. —Ed. Com.



Candle Powers
of
Electric Lamps, plotted on a
System of Polar Coördinates.

methods deserve a brief description. The standard to which all arc lights were referred was an Argand burner and "Methven's screen," loaned to the committee by Mr. Wright, of Weston's laboratory, which was accompanied by a certificate from the maker to its exactness as a two-candle standard.

It was tested against two standard candles and found to give the same light and to be much more uniform. This standard was placed at one end of a photometer bar of 450 cm. in length, at the other end of which was a 50-candle Swan lamp, serving as a secondary standard. This lamp was fed by a Brush storage battery, furnished and kept charged through the kindness of the representatives of the Brush Company. A second photometer bar making a small angle with the first, extended from this lamp into an adjoining room, where the arc lamp under test was suspended.

To permit of measurements of the light emitted from the arc lamp at various angles with the horizontal, the lamp was suspended from the end of an arm which was free to rotate about a horizontal axis parallel to the photometer bar, but vertically above it at such a height that when the arm was in a horizontal position the lamp could be suspended from its extremity with the arc on a level with the centre of the photometric disc. By this arrangement, when the end of the arm was raised the luminous point described a vertical circle whose axis was a line through the centre of the photometer disc and parallel to the bar. The radius of this circle was 127 cm. and the distance of its plane from the secondary standard 640 cm. At the centre of this circle was placed a mirror of glass, silvered on the back, at such an angle that the light from the arc lamp falling upon it was reflected along the axis of the circle upon the photometer disc. It will be seen that the distance between the lamp and mirror was thus rendered constant for all elevations of the lamp, that when the mirror was adjusted to reflect the light upon the disc, the angles of incidence and reflection were always 45°, and that the distance from the image of the lamp to the secondary standard was always 767 cm. The mirror was carefully tested for absorption and the proper corrections made in the computation of the result.

The general plan of making observations was as follows: The arm from which the lamps were suspended was made horizontal and the height of the lamp adjusted to bring the luminous point on a level with the centre of the mirror and photometer disc. Two observers

then adjusted and read the positions of the two discs ten times. The lamp was then raised by raising the end of the arm to which it was suspended and the readings repeated. This was continued until a sufficient number of positions had been taken.

Observations for current strength and for difference of potential between the binding posts of the lamp were made at frequent intervals while the photometric readings were in progress.

To facilitate the comparison of the arc lights with the standard, an apparatus was devised by which one-half or any larger fraction of the light could be cut off at pleasure. This apparatus consisted of a brass disc, about 30 cm. in diameter, having twenty-four sector-shaped openings, all equal to each other and to the metal portions that remained between. Upon this was placed another exactly similar disc, which could be so turned as to close any desired fraction of the openings.

This apparatus was mounted on a spindle placed parallel to the photometer bar, and in such a position that the light from the arc lamp must pass through the openings to reach the photometer disc. When the apparatus was made to revolve at only a moderate rate of speed it was impossible to detect the slightest flicker or inequality in the light in consequence of its use.

In the tests made by your committee, the apparatus was used, when used at all, with the sectors full open, when it was assumed to cut off one half the light as theory would indicate.

Experiment showed that if there is any error in this assumption it is far less than those arising from the unsteadiness of arc lights.

The tables below embody the results of all the tests.

In Table I, column 1 gives the altitudes of the lamp at which the illuminating power was actually measured.

Column 2 gives the true candle power for each altitude after applying all corrections. Each result given is a mean of ten observations.

Column 3, the mean of the observations for current.

Column 4, the mean of the observations for difference of potential between binding posts.

Column 5, the electrical energy consumed by the lamp in Watts.

Column 6, the same in horse-powers.

Column 7 gives the candle-powers for each 15° of altitude from the horizontal to 60°, as deduced from the curves given in X, Plate I.

Column 9 gives the candles per horse-power for the same elevations.

Under the head of remarks are given such observations as were made, during the progress of the tests, as to the working of the lamps.

Table II has been compiled to exhibit the results of the observations as to the steadiness of the light. The several columns give the ratios between the arc light and the standard for each of the ten observations for each altitude.

The plate shows, on a system of polar co-ordinates, the relative intensities of the various lamps tested, and the distribution of the light below a horizontal plane. The advantage of placing an arc lamp at a considerable elevation appears very clearly from an inspection of these curves.

TABLE I.—*Results of Tests on Arc Lamps.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp. Watts.	Energy in lamp. Horse-power.	Reduced results. Altitude.	Reduced results. Candles.	Reduced results. Candles per electrical H. P.	Remarks.
Arago	Horizontal	273	15·41	39·87	614·4	·824	Horizontal	273	332	Fifteen lamps in circuit.
	15° 30′	356					15°	350	425	
	30° 15′	505					30°	465	565	
	44° 30′	557					45°	583	708	
	56° 40′	644					60°	645	783	
Ball	Horizontal	233	6·60	48·83	322·3	·432	Horizontal	233	539	Seventeen lamps in circuit,
	19° 19′	431					15°	380	880	
	35° 05′	534					30°	520	1,204	
	46° 25′	346					45°	485	1,123	
	60° 00′	284					60°	182	421	
Brush (1,200)	Horizontal	180	6·62	52·50	347·5	·466	Horizontal	180	386	One lamp in circuit of dead resistance. Lamp very steady, and free from flicker.
	"	118						118	253	
	10° 26′	266					15°	332	712	
	22° 11′	439					30°	537	1,152	
	37° 30′	617					45°	613	1,316	
	47°	597					60°	355	762	
	56° 35′	422								

TABLE I.—*Continued.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Brush (2,000)........	Horizontal	389	10·32	56·73	585·5	·785	Horizontal	389	496	One lamp in circuit of dead resistance.
	12° 16′	575					15°	643	819	
	22° 11′	842					30°	1,082	1,379	
	32°	1,253					45°	1,373	1,750	
	58° 40′	1,246					60°	1,200	1,529	
Diehl....................	Horizontal	323	17·67	31·84	562·6	·754	Horizontal	323	428	Four lamps in circuit.
	26° 10′	673					15°	496	658	
	38° 30′	809					30°	725	961	
	56° 40′	881					45°	830	1,101	
							60°	887	1,176	
Richter........	Horizontal	313	20·19	30·00	605·7	·812	Horizontal	313	386	Six lamps in circuit. Very unsteady. Carbons fed periodically, the current, as shown by an ammeter in circuit, dropping almost to zero, then up to 25 ampères, falling gradually to about 18 ampères, and then dropping to zero again.
	14° 30′	691					15°	700	862	
	29° 15′	956					30°	960	1,183	
	41° 25′	813					45°	894	1,101	
	50° 30′	986					60°	603	743	
	57° 24′	633								

TABLE I.—*Continued.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Van de Poele...... (20-lights.)	Horizontal	451	16·91	37·88	640·5	·858	Horizontal	451	525	One lamp in circuit of dead resistance. Lamp frequently re-adjusted by exhibitor.
	15°	701					15°	708	825	
	28° 40′	1,020					30°	1,060	1,235	
	46° 25′	1,377					45°	1,377	1,604	
	56° 24′	848					60°	670	780	
Van de Poele...... (60-lt. machine.)	Horizontal	333	13·31	45·77	609·2	·817	Horizontal	333	408	One lamp in circuit of dead resistance. Constant flickering, and frequent fluctuations of considerable magnitude.
	16°	700					15°	535	655	
	34°	890					30°	900	1,101	
	46° 25′	1,156					45°	1,162	1,423	
	57° 24′	606					60°	500	612	
Western Electric	Horizontal	263	17·89	25·74	460·5	·617	Horizontal	263	426	Twenty-two lamps in circuit.
	30° 30′	355					15°	323	523	
	35° 15′	340					30°	355	575	
	46° 30′	247					45°	266	431	
	52°	183					60°	75	121	

TABLE II.—*Variations in Intensity of Lights while under Tests.*

	Horizontal.	15° 30′	30° 15′	44° 30′	56° 40′
ARAGO LAMP.					
	3·35	4·35	6·10	4·50	9·22
	4·64	3·93	5·73	4·76	4·97
	3·60	5·84	7·93	4·67	9·90
	1·87	4·23	6·46	5·84	5·99
	2·17	5·06	5·87	6·80	7·82
	4·10	3·44	6·68	8·60	9·22
	2·01	4·82	8·66	8·20	11·97
	5·27	3·23	7·13	5·88	14·86
	2·01	.....	8·48	9·22	8·90
	4·10	.....	4·26	15·10	7·67
Mean..............................	3·312	4·36	6·73	7·357	9·052
Standard..........................	69·2	68·4	63·06	63·54	50·76
Multiplier........................	1·192	1·192	1·192	1·192	1·192
Candles...........................	273	356	505	557	644
BALL LAMP.					
	Horizontal.	19° 19′	35° 05′	46° 25′	60° 00′
	2·77	7·12	5·84	5·66	1·49
	2·92	6·18	8·37	2·36	1·67
	3·31	6·85	9·90	4·03	1·63
	3·05	6·42	7·82	6·58	1·42
	3·64	6·18	9·76	2·65	4·38
	3·02	6·85	8·37	6·34	7·42
	3·68	6·94	6·85	9·22	3·68
	3·35	5·58	9·76	7·12	4·94
	3·31	7·12	10·18	4·03	8·96
	3·15	6·42	8·04	4·88	7·03
	....	....	....	....	6·85
	3·222	6·566	8·489	5·287	4·497
Standard..........................	60·6	55·04	52·76	55·46	53·06
Multiplier........................	1·192	1·192	1·192	1·192	1·192
Candles...........................	233	431	534	346	284

TABLE I.—*Results of Tests on Arc Lamps.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Arago....................	Horizontal	273	15·41	39·87	614·4	·824	Horizontal	273	332	Fifteen lamps in circuit.
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Ball........................	Horizontal	233	6·60	48·83	322·3	·432	Horizontal	233	539	Seventeen lamps in circuit,
	19° 19′	431					15°	380	880	
	35° 05′	534					30°	520	1,204	
	46° 25′	346					45°	485	1,123	
	60° 00′	284					60°	182	421	
Brush (1,200).........	Horizontal	180	6·62	52·50	347·5	·466	Horizontal	180	386	One lamp in circuit of dead resistance. Lamp very steady, and free from flicker.
	"	118						118	253	
	10° 28′	266					15°	332	712	
	22° 11′	439					30°	537	1,152	
	37° 30′	617					45°	613	1,316	
	47°	597					60°	355	762	
	56° 35′	422								

Table I.—*Continued.*

Lamp.	Altitude.	Candles.	Ampères.	Volts.	Energy in lamp.		Reduced results.			Remarks.
					Watts.	Horse-power.	Altitude.	Candles.	Candles per electrical H. P.	
Brush (2,000).........	Horizontal	389	10·32	56·73	585·5	·785	Horizontal	389	496	One lamp in circuit of dead resistance.
	12° 16′	575					15°	643	819	
	22° 11′	842					30°	1,082	1,379	
	32°	1,253					45°	1,373	1,750	
	58° 40′	1,246					60°	1,200	1,529	
Diehl.....................	Horizontal	323	17·67	31·84	562·6	·754	Horizontal	323	428	Four lamps in circuit.
	26° 10′	673					15°	496	658	
	38° 30′	809					30°	725	961	
	56° 10′	881					45°	830	1,101	
							60°	887	1,176	
Richter..........	Horizontal	313	20·19	30·00	605·7	·812	Horizontal	313	386	Six lamps in circuit. Very unsteady. Carbons fed periodically, the current, as shown by an ammeter in circuit, dropping almost to zero, then up to 25 ampères, falling gradually to about 18 ampères, and then dropping to zero again.
	14° 30′	691					15°	700	862	
	29° 15′	956					30°	960	1,183	
	41° 25′	813					45°	894	1,101	
	50° 30′	986					60°	603	743	
	57° 24′	633								

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	57° 24′	633								

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	28° 40′	1,020					30°	1,060	1,235	
	46° 25′	1,377					45°	1,377	1,604	
	56° 24′	848					60°	670	780	
Van de Poele...... (60-lt. machine.)	Horizontal	333	13·31	45·77	609·2	·817	Horizontal	333	408	One lamp in circuit of dead resistance. Constant flickering, and frequent fluctuations of considerable magnitude.
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TABLE II.—*Variations in Intensity of Lights while under Tests.*

ARAGO LAMP.

	Horizontal.	15° 30′	30° 15′	44° 30′	56° 40′
	3·35	4·35	6·10	4·50	9·22
	4·64	3·93	5·73	4·76	4·97
	3·60	5·84	7·93	4·67	9·90
	1·87	4·23	6·46	5·84	5·99
	2·17	5·06	5·87	6·80	7·82
	4·10	3·44	6·68	8·60	9·22
	2·01	4·82	8·66	8·20	11·97
	5·27	3·28	7·13	5·88	14·86
	2·01	.....	8·48	9·22	8·90
	4·10	.....	4·26	15·10	7·67
Mean...............................	3·312	4·86	6·73	7·357	9·052
Standard..	69·2	68·4	63·06	63·54	50·76
Multiplier........................	1·192	1·192	1·192	1·192	1·192
Candles............................	273	356	505	557	644

BALL LAMP.

	Horizontal.	19° 19′	35° 05′	46° 25′	60° 00′
	2·77	7·12	5·34	5·66	1·49
	2·92	6·18	8·37	2·36	1·67
	3·31	6·85	9·90	4·03	1·63
	3·05	6·42	7·82	6·58	1·42
	3·64	6·18	9·76	2·65	4·38
	3·02	6·85	8·37	6·34	7·42
	3·68	6·94	6·85	9·22	3·68
	3·35	5·58	9·76	7·12	4·94
	3·31	7·12	10·18	4·03	8·96
	3·15	6·42	8·04	4·88	7·03
	....	....	....	....	6·85
	3·222	6·566	8·489	5·287	4·497
Standard..........................	60·6	55·04	52·76	55·46	53·06
Multiplier........................	1·192	1·192	1·192	1·192	1·192
Candles............................	233	431	534	346	284

Brush (1,200 Candles).

Horizontal.	Horizontal.	10° 26′	22° 11′	37° 30′	47° 00′	56° 35′
2·68	1·67	4·53	6·42	9·76	9·76	5·84
3·11	1·85	4·59	7·08	10·64	11·27	9·35
3·05	1·81	4·23	7·62	11·11	8·96	7·42
3·11	1·33	4·64	7·62	10·33	10·18	9·62
2·88	1·29	4·33	7·42	9·48	9·48	7·72
3·05	2·53	4·53	7·12	9·48	10·04	6·16
2·83	2·83	4·33	7·42	9·48	9·00	7·92
3·08	1·87	4·13	7·08	9·76	9·76	6·18
2·89	2·71	4·48	7·32	9·90	8·48	6·42
2·77	1·53	4·33	6·34	10·04	9·62	2·53
2·94	1·942	4·41	7·134	9·908	9·664	6·916
54·25	51·06	50·82	51·56	51·74	51·82	51·14
1·192	1·192	1·192	1·192	1·192	1·192	1·192
180	118	266	439	617	597	422

Brush (2,000 Candles).

	Horizontal.	12° 16′	22° 11′	32°	58° 40′
	3·64	5·00	10·33	9·76	14·16
	4·08	4·94	10·38	10·79	16·92
	4·28	5·95	6·34	12·51	14·86
	4·88	4·13	6·94	12·70	13·10
	3·27	6·26	6·50	10·18	11·27
	2·92	4·38	7·32	15·59	14·63
	3·61	6·26	7·42	11·78	5·45
	3·05	4·23	7·52	10·33	9·76
	4·48	8·04	7·22	9·62	10·33
	1·99	4·43	6·50	13·31	6·08
	......	......	......	12·33	......
Mean..............................	3·623	5·362	7·642	11·72	11·656
Standard..............	45·05	44·96	46·26	44·84	44·84
Multiplier......................	1·192	1·192	1·192	1·192	1·192
Disc Multiplier............	2·	2·	2·	2·	2·
Candles..........................	389	575	842	1253	1246

Diehl Lamp.

	Horizontal.	26° 10′	38° 30′	56° 40′
	2·19	6·26	4·76	12·70
	1·77	7·82	7·72	13·51
	1·01	6·18	9·76	9·90
	1·55	7·82	13·51	13·51
	4·28	6·26	9·22	11·96
	7·12	7·82	11·11	9·00
	7·42	7·52	7·82	8·84
	5·68	8·72	12·70	9·35
	1·46	10·95	12·90	9·76
	3·98	7·92	4·94	9·35
Mean	3·646	7·727	9·444	10·797
Standard	74·38	73·02	71·80	68·44
Multiplier	1·192	1·192	1·192	1·192
Candles	323	673	809	881

Richter Lamp.

	Horizontal.	14° 30′	29° 15′	41° 25′	50° 30′	57° 24′
	5·06	10·79	15·59	6·26	7·12	3·02
	5·24	13·94	16·11	8·60	10·18	8·60
	6·85	12·70	14·68	8·04	8·37	4·94
	6·18	12·70	15·59	8·60	7·12	4·33
	3·88	13·31	14·39	7·52	10·33	5·68
	3·35	9·90	18·72	5·68	10·04	4·76
	4·76	11·44	18·09	5·00	7·42	3·39
	7·32	11·27	15·59	6·58	7·32	7·62
	6·67	14·16	18·40	6·94	8·96	8·60
	5·38	11·27	16·11	7·52	9·90	6·00
Mean	5·469	12·148	16·32	7·074	8·676	5·694
Standard	48·00	47·74	49·14	48·20	47·64	46·64
Multiplier	1·192	1·192	1·192	1·192	1·192	1·192
Disc Multiplier	....	....	....	2·	2·	2·
Candles	313	691	956	813	986	633

Van de Poele (20 Light Circuit).

	Horizontal.	15°	28° 40′	46° 25′	50° 24′
	5·76	·926	6·94	8·04	1·63
	7·08	1·42	3·39	3·98	1·42
	2·83	1·75	3·56	3·08	1·51
	4·03	1·73	4·23	4·94	3·27
	4·28	4·43	4·48	5·60	2·74
	1·55	2·09	4·38	4·45	2·39
	1·87	7·62	3·05	7·62	2·68
	3·08	4·76	4·13	6·76	4·23
	3·60	2·25	3·64	......	6·03
	3·19	2·30	3·68	......	6·10
Mean..............................	3·722	2·928	4·148	5·63	3·200
Standard........................	101·70	100·45	108·04	102·64	111·20
Multiplier......................	1·192	1·192	1·192	1·192	1·192
Disc Multiplier............	....	2·	2·	2·	2·
Candles	451	701	1020	1377	848

Van de Poele (60 Light Circuit).

	Horizontal.	16°	34°	46° 25′	57° 24′
	3·39	9·1	15·10	15·85	4·08
	4·18	8·86	16·09	8·84	7·22
	3·02	9·90	14·16	11·27	10·79
	3·80	7·23	17·47	7·62	12·51
	3·84	9·90	10·97	13·51	1·75
	6·34	5·58	2·80	15·10	2·11
	2·59	6·78	6·18	17·79	7·52
	3·80	9·22	8·74	18·40	5·84
	4·13	8·37	6·18	11·78	8·04
	4·33	7·43	6·76	15·34	11·11
Mean	3·942	8·237	10·445	13·55	7,097
Standard........................	70·94	71·30	71·38	71·54	71·68
Multiplier......................	1·192	1·192	1·192	1·192	1·192
Candles..........	333	700	890	1156	606

...ERN ELECTRIC.

30° 30′	35° 15′	46° 30′	52°
6·94	4·64	3·56	2·62
2·98	5·12	3·88	2·80
3·80	4·28	5·38	3·72
5·12	5·38	2·25	3·68
5·06	5·18	1·60	1·63
5·12	7·72	3·98	2·68
8·72	3·08	3·84	2·59
4·70	6·00	4·33	3·19
7·32	6·58	6·26	4·18
5·76	6·58	5·68	4·38
5·552	5·456	4·085	3·147
53·56	52·22	50·06	48·8
1·192	1·192	1·192	1·192
355	340	247	183

are those by which the intensity of the stand... of arc lamps, as observed. This product is to... llow for loss by reflection, and when the revolv... ct is the intensity of the arc lights in candles. ...n any one column is therefore a measurement... at altitude. If the actual variations are desired... ultiplied by the intensity of the standard, by 1... and when disc is used by 2.

The foregoing is respectfully presented by

WILLIAM A. ANTHONY, *Chairman.*

C. F. BRACKETT,
G. MORGAN ELDRIDGE,
CHARLES B. DUDLEY,
OSCAR S. BUSSMANN,
T. C. MENDENHALL,
WM. E. GEYER,
CHAS. A. YOUNG,
A. B. WYCKOFF,
CARL HERING,
CHAS. R. CROSS.

J. B. MURDOCK, *Secretary*

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

SECTION VI.—CARBONS FOR ARC LAMPS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section VI, on Carbons for Arc Lamps.

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *May*, 1885.

Prof. M. B. SNYDER,
Chairman of Board of Examiners,
International Electrical Exhibition:

With the permission of Prof. Anthony, Chairman of Group B, I herewith submit separately the report of Section VI, "on Carbons for Arc Lamps." It includes chemical analyses by Dr. Dudley, Prof. Greene and the chairman, a thorough series of specific gravity determinations by A. E. Outerbridge, Jr., a microscopical study of their transverse sections by Dr. Persifor Frazer, and a table of resistances of the carbons, both plain and copper-coated, made by Prof. Wm. A. Anthony.

Respectfully,

SAMUEL P. SADTLER,
Chairman of Section VI.

CHAS. B. DUDLEY,
Secretary of Section VI.

PHILADELPHIA, *May*, 1885.

Section VI had submitted to it for inspection and report the carbons from five exhibitors, viz.:

1. The Brush Electric Company.
2. The Wallace Carbon Company.
3. The Boulton Carbon Company.
4. The Buffalo Carbon Company.
5. The Carré carbons, manufactured by Emile Levy, Paris, and exhibited by Messrs. J. W. Queen & Co.

Of these, the Brush, Wallace, and Boulton companies submitted plain and copper-coated carbons, the Buffalo Company a homogeneous carbon, both plain and copper-coated, and, in addition, a carbon with a core of pure graphite inserted in a sheathing of coke and a carbon with a vitrified coating, while Queen & Co. offered only the uncoated Carré carbons.

It was determined to have chemical, physical and mechanical studies made of these carbons, but the study of the physical characters, resistance, duration of burning in the lamp under different conditions of current, etc., was handed over to the Section on Arc Lights, whose chairman, Prof. William A. Anthony, agreed to take this part of the work.

[A report on the resistance tests came in after this was written, and is appended.]

The chemical and mechanical study was apportioned out among the members of the Section who now present this report, and included determinations of the percentage of carbon, hydrogen and ash, with a qualitative examination of the chief constituents of the latter in the several plain or uncoated samples, the amount of copper on the coated carbons, both absolutely by weight and relatively per unit of length; specific gravity determinations on the uncoated carbons, both with sections of the solid carbons of given length and with the pulverized material; and, lastly, a microscopical study of the structure of the carbon pencils, using for this purpose specially prepared thin cross-sections. The aid of micro-photography has also been availed of in this latter case for the proper illustration of the results.

1. Determination of the percentage composition of the uncoated carbons (carbon, hydrogen and ash).—This was undertaken by Professor Samuel P. Sadtler, and was made to include five samples, viz.: the plain Brush, Wallace and Boulton carbons, the plain solid Buffalo carbon and the Carré carbon. The Buffalo carbon with the graphite

core was not analyzed, as the agent of the company said that the sheathing was made exactly of the same materials and by the same methods as the solid carbon exhibited, while the pure graphite core had a sufficiently well-known composition.

The greater part of a single pencil having been reduced to fine powder, the material for analysis was taken from this stock. The determinations were made by the methods of ultimate analysis, using an open tube, three-fourths filled with granular cupric oxide, placing the weighed material in a platinum boat, and conducting over this a slow stream of oxygen. In this way, besides the carbon and hydrogen determinations, the ash could be accurately weighed, and a check established upon the whole.

The results were as follows:

	Brush Carbons.			*Wallace Carbons.*		
	I.	II.	Average.	I.	II.	Average.
Carbon	97·61	97·81	97·71	95·92	......	95·92
Hydrogen	1·32	1·22	1·27	1·15	0·97	1·06
Ash	0·64	0·61	0·63	2·94	2·80	2·87
Occluded air or loss	0·43	0·36	0·39	......		0·15
	100·00	100·00	100·00	100·01		100·00

	Boulton Carbons.			*Buffalo Carbons.*		
	I.	II.	Average.	I.	II.	Average.
Carbon	98·19	98·24	98·21	97·68	......	97·68
Hydrogen	0·72	......	0·72	1·51	1·60	1·55
Ash	0·87	0·88	0·87½	1·09	1·08	1·09
Occluded air or loss	0·22		0·19	......		......
	100·00	99·12	99·92	100·28		100·32

	Carré Carbons.		
	I.	II.	Average.
Carbon	95·98	95·84	95·91
Hydrogen	1·00	0·73	0·86
Ash	1·91	1·83	1·87
Occluded air or loss	1·11	1·60	1·36
	100·00	100·00	100·00

In looking at these figures, several points of interest at once present themselves.

The Brush carbons have the smallest ash of the series. On account of their rather more open and porous structure, there is room for occluded air in this case, as the result shows.

The Wallace carbons have the largest amount of ash of the serie

The character of this ash will be noted farther on by another member of the Committee. This carbon is closer in structure than the Brush carbon, being made in an entirely different way, and there is no occluded air to look for.

The Boulton carbons, though having a higher percentage of ash than the Brush carbons, have a higher carbon and a lower hydrogen percentage, possibly having been burned at a higher temperature.

The Buffalo carbons show a distinctly higher percentage of ash than the Brush or the Boulton carbons. The hydrogen percentage as given is possibly a little too high, as the summing up seems to show.

The Carré carbons show a large ash, although considerably less than the Wallace carbons. The porous structure of these hydrocarbons offers, no doubt, a partial explanation for the relatively large percentage of occluded air and loss.

2. *Determination of the percentage of ash and qualitative examination of same.*—This was undertaken by Dr. Charles B. Dudley, and the examination was made upon a portion of the same pulverized material as that used by Prof. Sadtler in the combustion analyses. The results were as follows:

The Brush carbons yielded 0·478 per cent. of ash. A qualitative examination showed that the portion insoluble in acids was slight; that there was a considerable amount of ferric oxide and a trace of magnesia.

The Wallace carbons yielded 2·672 per cent. of ash. A qualitative examination showed a large insoluble residue and a large amount of the oxides of copper and iron.

The Boulton carbons yielded 0·892 per cent. of ash. A qualitative examination showed a small insoluble residue only, a large amount of ferric oxide and a trace of magnesia.

The Buffalo carbons yielded 1·104 per cent. of ash. A qualitative examination showed a small insoluble residue, much ferric oxide, and a trace of magnesia.

The Carré carbons yielded 2·086 per cent. of ash. A qualitative examination showed considerable insoluble residue, much ferric oxide, and considerable lime.

It will be seen that these ash determinations correspond quite generally, in some cases with great exactness, to those gotten in connection with the combustion analyses of the carbons.

Sample.	Length of coating.	Copper on length of 4 c. m.	Copper per centimetre.	Total copper (not including that on end).
Brush carbon......	281 millimetres.	·1621 grammes.	·040525 grammes.	1·1388 grammes.
Wallace carbon...	297 "	·0180 "	·00 "	0·1337 "
Boulton carbon...	272 "	·1853 "	·046325 "	1·2600 "
Buffalo solid carbon..................	262 "	·1010 "	·02525 "	0·6616 "
Buffalo core carbon..................	253 "	·1525 "	·038125 "	0·9645 "

3. Determinations of copper on the copper-coated carbons.—These were made, by Prof. Wm. H. Greene, upon the samples of the Brush Company, the Wallace Company, the Boulton Company, and both the homogeneous and the graphite-core carbon of the Buffalo Company. No copper-coated sample of the Carré carbon was exhibited. The results are given in tabular form on page 17.

4. Specific gravity determinations.—These were undertaken by A. E. Outerbridge, Jr., and were made upon the uncoated carbons of the Brush, Wallace and Boulton Companies, the French Carré carbon and the plain, the graphite-core and a glazed carbon of the Buffalo Company.

A superficial examination of these carbons showed that some of them were much more porous and of coarser grain than others; it was thought advisable, therefore, to make two different determinations of each sample, one for the purpose of ascertaining the specific gravity of the pencil and the other the specific gravity of the material of which the pencil is composed.

For the first method the samples were all cut to the same length, viz., 5 centimetres. These were first heated to a moderate temperature to expel the moisture absorbed in their pores and further dried in a desiccator; when quite cool they were weighed upon a delicate analytical balance, sensitive to less than one-tenth of a milligram. The pencil was then coated with shellac varnish to prevent the absorption of water when immersed. When the thin coating of shellac was hard the sample was suspended from the beam by a filament of silk and reweighed; this was the weight used in the specific gravity determinations. The sample was then immersed in a beaker glass of distilled water at 60°F. and weighed. The specific gravity of the pencil was then determined by the usual calculation.

In order to determine the specific gravity of the material of which the pencils are composed, it was first ground to a fine powder in a steel mortar, put through a "No. 80" sieve, warmed to expel moisture, dried in the desiccator and weighed. The weight taken in this case was usually two grammes. The specific gravity bottle which was used in these determinations was filled each time with distilled water at, or very near, 60°F., and weighed; the water was then poured out, the powder put in, the bottle refilled with water (care being taken that no air-bubbles remained) and reweighed; from which data the specific gravity of the sample was determined.

In addition to the above, two other experiments were made, as follows: The pencil was broken up in the mortar and the finest particles separated by the sieve; the coarser grains were weighed, thrown into distilled water and boiled. The water was then cooled down to 60°F., the granules transferred to the specific gravity bottle and a new determination made. In both cases, the specific gravity was much higher than that of the finely powdered portion of the same sample, as will be seen from the tabular statement appended. This would seem to indicate that some volatile gas was driven off during the process of boiling.

A further observation was made, viz.: that the material composing the pencils is not of uniform density. When the sample is finely powdered, thrown into water and stirred with a glass rod, a portion sinks, but another portion (somewhat like an oily scum) floats upon the surface. This is doubtless some pitch or tar compound used to cement the materials together. Most of the carbons used in actual practice are coated with a superficial layer of copper, and as this would render specific gravity determinations of no value, the plain carbons only were used with the exception of one sample exhibited by the Buffalo Co., covered with a coating of borate of lead. There was also a carbon pencil examined having the peculiarity of a central core (resembling graphite) a little larger in diameter than the core of an ordinary lead pencil.

It was noticed when these different determinations were tabulated that the specific gravity of the powdered carbon was (as might be expected) in each case greater than that of the pencil, and furthermore that the pencils showing the highest specific gravities were not made from the densest materials. Considerable difference was also noticed in the hardness of the different samples.

The figures given in these tables are the average of two weighings of the same sample after drying.

Carbon Pencils.

Name of Sample.	Length.	Weight.	Specific Gravity.
Brush	5 centimetres.	7·8035 grammes.	1·526
Wallace	do.	8·5067 "	1·571
Boulton	do.	7·7162 "	1·516
Buffalo—plain	do.	7·7272 "	1·523
Buffalo—graphite core	do.	7·0540 "	1·415
Buffalo—vitrified	do.	8·5961 "	1·598
Carré	do.	8·6091 "	1·506

Ground Carbon.

Name of Sample.	Weight.	Specific gravity
Brush	2 grammes.	1·587
Wallace	do.	1 806
Boulton	do.	1·606—1·540 Average, 1·573
Buffalo—graphite core	do.	{centre core, 1·699 / exterior, 1·594}
Buffalo—vitrified	do.	1·865
Carré	do.	1·885—1·914 Average, 1·8995

The following table shows the specific gravity of the two coarsely powdered samples which were boiled in distilled water.

Brush carbon	2 grammes taken	sp. gr., 1·908
Carré	do	sp. gr., 1·982

5. *Microscopical examination of thin transverse sections of the carbons.*—This was made by Dr. Persifor Frazer and yielded the following very interesting results.

The examination of the five thin sections of the electric light carbons submitted was undertaken with an 8–10 Zentmayer lens and a Beck parabolic reflector.

The sections were in fair order (with the exception of some dirt on the inner surfaces of the cover glasses) except that No. 5 was broken across the cover glass and the latter as well as the carbon section detached from the slide

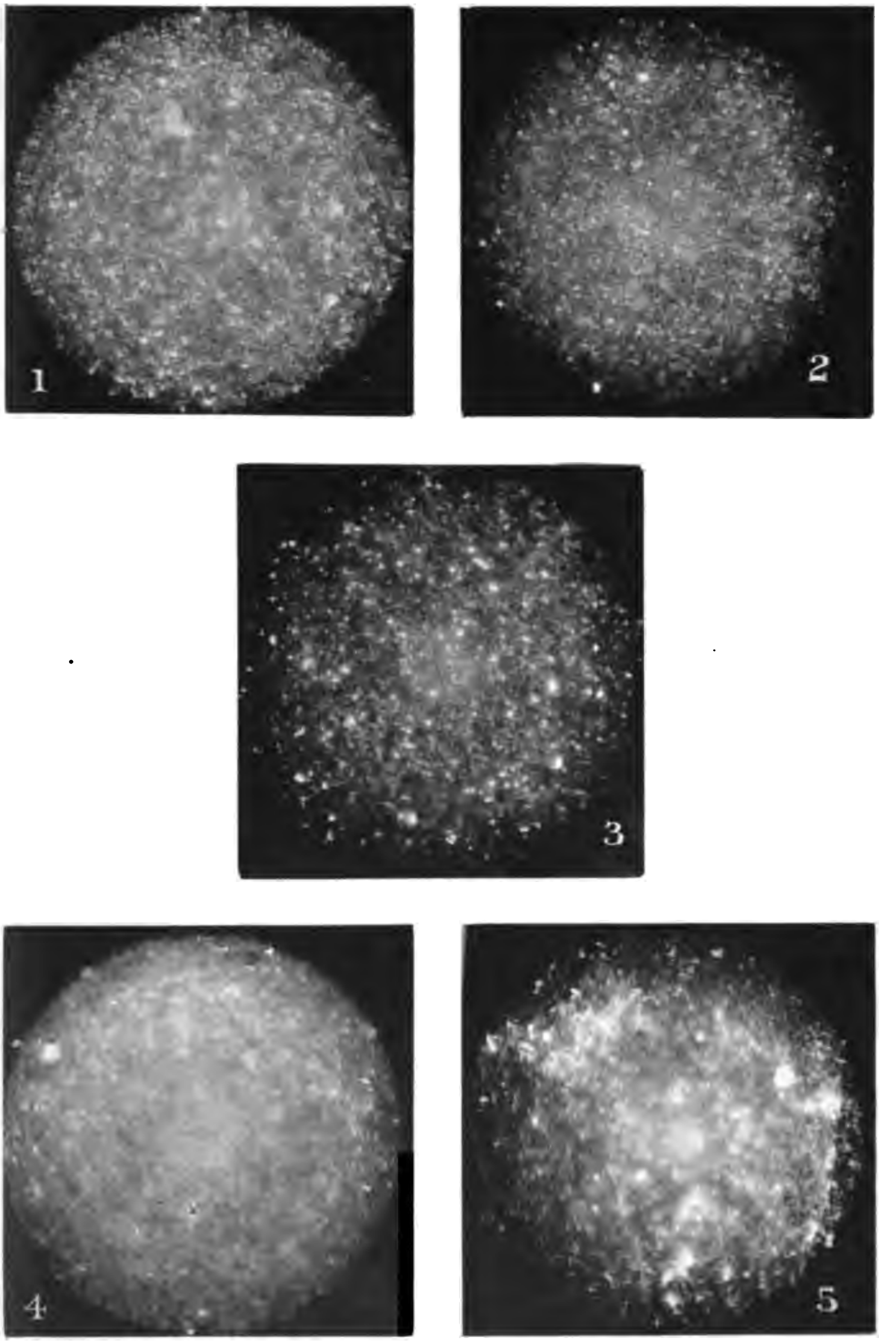

PHOTO-COLLOTYPE WELLS & HOPE CO.

CARBONS FOR ARC LAMPS.

Photographs through the Microscope of thin Sections of Electric Light Carbons, to accompany Dr. Frazer's report.

No. 1, was taken from a Brush carbon.

No. 2, was taken from a Wallace carbon.

No. 3, was taken from a Boulton carbon.

No. 4, was taken from the Buffalo Co.'s carbon.

No. 5, was taken from the Carré carbon.

The preliminary examination was made without a reflecting mirror and with a low eye-piece giving a magnifying power of about 50 diameters.

No. 1. Under these circumstances No. 1 presented an opaque surface except in a few spots where the film was torn away, and a few translucent particles. The color of its surface was silver gray with foliated masses of carbon of decidedly graphitic appearance distributed through the field.

Under the reflected light of the parabolic mirror the substance of the section, though of coarser structure than appeared in the other slides, seemed of considerable constancy of composition.

The largest grains were about 0·1 mm., and the smallest 0·03 mm., the latter measurement quite accurately representing the size of the pores. All the bright spots are surfaces showing high metallic lustre and gray color, with lines of striation and fracture.

No. 2. Without the reflector, No. 2 presented the appearance of a fine-grained surface covered with small rounded nodules or minute botryoidal masses, and showed little if any traces of foliation or crystallization.

Under reflected light (and exposed on the underside to a parallel beam) the largest opaque grains were 0·03 mm. and the smallest 0·015 mm. The average size of the opaque grains was 0·02 mm. These are, in a rough estimate, from 1 to 2 per cent. of visible foreign matter in the carbon in the form of grains of various substances (which are generally translucent) in the carbon. Some of these reach a size of 0·1. There are fewer pores in this than in No. 1, but those which exist are larger.

The largest part of the substance is very fine grained, but large dark gray angular discs are very generally distributed throughout the mass. In the photograph these dark gray flat bodies are visible, and the constituent parts of the fine mass are less sharply defined and separated. But, in fact, the photograph cannot give either the color or the lustre of the original, and is mainly useful in giving an idea of the texture of the surface.

No. 3. Without the reflecting mirror, No. 3 showed an extremely fine-grained texture with comparatively few and quite small points of silver-gray color and metalloid lustre.

Under the mirror, the grains measured from 0·05 to 0·02.

The texture was extremely fine-grained and compact, and the structure exceedingly homogeneous. The color of the surface was a lighter gray than that of any of the other slides, and was tinged yellowish in irregular blotches which may, however, have been the result of the accidental addition of a foreign body in mounting. Occasional translucent oblong particles were seen measuring 0·1 mm. to 0·05 mm. along their longer sides.

The surface exhibits small and large masses of slightly greenish color attached to each other and nowhere separable into distinct grains. The smallest of these constituent parts are not so small as those of the matrix of No. 2; and the largest, not as large as the dark angular fragments in the same slide. The structure is nowhere compact, but loose and spongy. There are visible a few small striated particles of irregular outline.

No. 4. Without the mirror the texture appears very fine, but little granular in character. The very small points of steel-gray color of graphitic aspect are less numerous than in 2 and 3.

With the reflector, the grains varied in size from 0·01 mm. to 0·03 mm., the average being rather nearer to the first measurement. The color was a somewhat darker gray than that of No. 3, and the number of very minute particles of foreign matter was greater, most of these were translucent and measured about 0·02 mm.

No. 5. Examined simultaneously in reflected and transmitted light, No. 5 shows a very large number of holes which have doubtless been caused by the more ready crumbling of certain of its constituent grains. Those of the latter which are opaque measure from 0·02 mm. to 0·01 mm. The grains are not so fine as in the last specimen, and the structure seems to be less homogeneous.

From the existence of numerous very fine points of various colors in transmitted light, and the existence of the holes formerly mentioned, it would seem that the powdered carbon has been mixed with very fine sand or earth, either accidentally or purposely, before having been moulded into sticks.

The ground mass has a fine grained, dark greenish appearance of the same character as that of 3 and 4, *i. e.*, resembling a surface of a

decomposing mineral. A number of dark gray, flat, angular objects are scattered through the mass as in No. 2.

RESISTANCES OF ARC LIGHT CARBONS.

The following measurements of resistances of electric light carbons were made at Cornell University last winter. The carbons were selected at random from those which Professor Sadtler procured for tests, and probably represent a fair average.

The method pursued in measuring the resistances was as follows: The carbon to be tested was connected in circuit with a piece of very uniform German silver wire, a known length of which measured $\frac{1}{10}$ ohm. To connect the carbon in the circuit, a hole, which the carbon fitted tightly, was bored in the side of a wooden block, and a second hole bored from the top of the block to meet the first. Such a block was fitted upon each end of the carbon and the vertical holes filled with mercury. Into this the connecting wires were placed. The resistance of the carbon was determined by obtaining, upon the German silver wire, points having the same difference of potential as points on the carbon near the two ends. Measuring the distance between these points on the German silver wire, and comparing with the known length for $\frac{1}{10}$ ohm, gave the resistance of the carbon. To determine the points of equal difference of potential, a Thomson galvanometer of 10,000 ohms resistance, differentially wound, was used. The coils were adjusted so that no deflection occurred when the same current flowed in opposite directions through them. Their resistances were also adjusted to exact equality. The terminals of one pair of coils were then connected with points near the ends of the carbon, and the terminals of the other pair with sliding contacts on the German silver wire. The method of using the instrument will now be evident. It was far more sensitive than was necessary for the purpose, but could nevertheless be used with great facility. The measurements were made by Mr. E. T. Turner, a young man doing some post-graduate work in my laboratory. The results are given in the table below:

Resistances of Carbons.

No. of Carbons.	Resistance per Centimeter.	Total Resistance of 30 c.m.
WALLACE (PLAIN).		
	ohm.	
1	0·0048	0·134
2	0·0044	0·132
3	0·0047	0·141
(COPPERED.)		
4	0·0044	0·132
5	0·0031	0·093
BUFFALO COMPANY (VITRIFIED).		
	0·0050	0.150
2	0·0066	0·198
3	0·0061	0·183
BRUSH (PLAIN).		
1	0·00610	0·183
2	0·00623	0·187
3	0·00672	0·222
4	0·00091	0·227
(COPPERED.)		
1	0·00108	0·0324
2	0·00033	0·0099
3	0·00024	0·0072

No. of Carbons.	Resistance per Centimeter.	Total Resistance of 30 c.m.
BUFFALO (PLAIN).		
1	0·00625	0·187
2	0·0052	0·156
(COPPERED.)		
1	0·00221	0·076
2	0·00940	0·0144
3	0·00075	0·0225
CORED (PLAIN).*		
1	0·1413	4·239
2	0·1700	5·100
(COPPERED.)		
1	0·000422	0·01266
2	0·001617	0·04851
BOULTON (COPPERED).		
1	0·00163	0·0489
2	0·00218	0·0654
3	0·000475	0·001425
CARRÉ (PLAIN).		
1	0·00408	0·1224
2	0·00377	0·1131

*This was a hollow carbon having a core of some different material. To make sure that the high resistance was not a mistake, it was measured also in the ordinary way by the bridge, with the same results.

Respectfully submitted,

SAMUEL P. SADTLER, *Chairman Section VI.*

CHAS. B. DUDLEY, PERSIFOR FRAZER,

WM. H. GREENE, WILLIAM A. ANTHONY,

A. E. OUTERBRIDGE, JR.

NOTE.—Sincere thanks are due to Mr. William Curtis Taylor for the care, skill and time he has contributed to render the photographic plate as successful as possible. P. F.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTION X.

(*SECTION I, CLASS VI, OF THE CATALOGUE.*)

STEAM BOILERS

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, JULY, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE
1885.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman.*

CHARLES BULLOCK,

THEO D. RAND,

COLEMAN SELLERS,

WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION X.—STEAM BOILERS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section X, on Steam Boilers.

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

PROF. M. B. SNYDER,

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section X (on Steam Boilers), respectfully present the following report.

H. W. SPANGLER, *for Section X.*

PHILADELPHIA, *December*, 1884.

REPORT ON STEAM BOILERS.

U. S. S. Tennessee, NEW ORLEANS, LA.
February 13, 1885.

To the Chairman of the Board of Examiners on Steam Boilers.

GENTLEMEN :—Enclosed I send you a copy of the results of tests made during the late International Electrical Exhibition, together with an account of the methods used, and the deductions from the results.

The drawings of all the boilers are in the possession of Professor Marks, and I would recommend that they be reproduced for the report. I have not that data with me which can be taken directly from the drawings, and have left blanks wherever, in the description of the boilers, data should be filled in.

The thanks of the Committee are due to the Crosby Steam Gauge and Valve Company, for the use of their standard steam gauges and test pumps; also to Mr. M. B. Edson for his recording and alarm gauge, which was used in each of the tests; also to the Blake Manufacturing Company, for the use of two pumps for feeding boilers during the tests; and to Riehlé Brothers and Mr. Troemner for the use of scales during the tests.

The following named young men rendered valuable assistance in observing and recording the data during the tests, and are especially entitled to the thanks of the Committee.

Geo. R. Green,	H. Szlapka,	Leon Kraft,
Charles H. Small,	F. Thibault,	Richard McCall,
George K. Fischer,	E. E. Alcott,	R. L. Rutter,
W. F. Lubbe,	Wm. A. Bigler,	D. E. Tracy,
L. F. Roudinella,	Theodore Gould, Jr.,	Joseph Israel,
	Thos. Grier..	

All the calculations have been checked at different times by different computers.

Hoping the results and methods have been satisfactory to the Committee,

I am, very truly yours,

H. W. SPANGLER (*for Section X*),
Assistant Engineer, U. S. Navy.

Code of the Proposed Quantitative Tests for the Evaporative Efficiency of Boilers at the International Electrical Exhibition, by the Franklin Institute, of 1884.

SPECIAL NOTICE.

Boilers may be exhibited and used at the International Electrical Exhibition, but will not have quantitative tests made of their efficiency unless formal application is made, and the subjoined code accepted before July 15, 1884.

Competitive tests will not be made unless at the joint request of the

parties desiring a competitive test, and after they have agreed to and subscribed to this code, and fixed upon a rating for the points enumerated in Article 4.

The Committee of judges reserve the right to limit the number of tests made, should time and opportunity not permit all the tests desired to be completed.

SECTION I.—PRELIMINARIES TO THE TESTS.

ARTICLE 1. (Capacity.) The boilers entered may be of any capacity having an evaporative power, not less than seven hundred and fifty pounds of water per hour.

Each boiler must be so drilled as to enable its whole internal capacity to be determined by being completely filled and emptied of water. Proper cocks, piping, etc., must be so placed as to enable this to be done readily.

ART. 2. (Pipes and Valves.) Each exhibitor will furnish all the pipes and valves necessary to make connection with the main water and steam pipes in a proper manner, and subject to the orders of the Superintendent. He will also make any alterations in water and steam pipes required for the tests, furnishing all tools, piping, cocks, and mechanical labor at his own cost.

ART. 3. (Space.) Each exhibitor will be furnished with space at the regular rates established for the exhibition, in which space he must build his foundations and boiler setting, and make connection with the chimney flue, if required, at his own cost, and subject to the approval of the Superintendent.

ART. 4. (Specifications.) Each exhibitor must furnish to the Chairman of the committee of judges on steam boilers, such description and drawing, both of the boiler in position and of the details of the boiler, as will facilitate the labor of that committee, together with his claims as to meritorious points for his exhibit.

The following points will have special consideration :

1. Economy of fuel.
2. Economy of material and labor of Construction.
3. Evaporative power. (Space occupied.)
4. Simplicity and accessibility of parts.
5. Durability of whole structure.

Exhibitors desiring a competitive test made, must agree upon a rating for these points before it will be made.

Exhibitors must also file the following data :

Area of heating surface to the nearest hundredth of a foot.
Area of grate surface to the nearest hundredth of a foot.
Area of calorimeter to the nearest hundredth of a foot.
Area of chimney flue to the nearest hundredth of a foot.
Height of chimney required.
Number of pounds of coal per square foot of grate to be burned per hour.

Should the calculations of the committee of judges differ in result from

those of the exhibitor, he will be required to give all the details of his calculations, and an agreement must be reached before proceeding with the test.

SECTION II.—PREPARATIONS FOR THE TESTS.

ART. 5. (Coal). Anthracite coal will be used and will be furnished free of charge, provided the steam made is used for the general purposes of the Exhibition.

The same quality and size of coal will be used in all the tests, unless special arrangements be made for another kind of fuel.

An analysis will be made of the coal used. The coal will be weighed to the boiler.

ART. 6. (Water). The water used will be taken from the city mains. The feed water for the boilers will be weighed by means of scales and a large tank, and will be run into a smaller supplemental tank, from which it will be pumped into the boiler by means of a feed pump actuated by steam from the boilers.

The temperature of the feed water will be taken by means of a standard thermometer, in the supplemental tank.

ART. 7. (Pressure.) The steam pressure used shall not exceed ninety pounds per square inch by the guage, unless by special arrangement with the committee of judges.

A standard guage will be used and also a standard thermometer immersed in a mercury pocket in the steam space.

ART. 8. (Safety Valve.) The safety valve will be set to blow off at ten pounds above the pressure fixed upon.

ART. 9. (Leaks.) Within twenty-four hours preceding the test of a boiler, it must be subjected to hydraulic pressure, ten pounds greater than its steam pressure during the test, and proved to be perfectly tight.

ART. 10. (Attendants.) The attendants in charge of the boiler tested must be approved by the party whose boiler is tested and by the judges. All attendants are to be subject to the orders of the judges during the progress of the test.

ART. 11. (Ashes.) All ashes will be weighed on being withdrawn from the ash pit, and must not be damped until weighed.

ART. 12. (Calorimeters.) The calorimeters used will consist of a barrel, scale and hand thermometer. Two calorimeters will be used and simultaneous observations made at fifteen minute intervals.

ART. 13. (Fires.) The exhibitor shall be allowed one day previous to the test to clean boilers and grates.

The steam having reached the required pressure, the ash pit shall be thoroughly cleaned and swept, and thereafter the fire maintained as nearly uniform as possible, the test closing with the same depth and intensity of fire as it opened.

This point is to be decided by the judges who may make allowance if it be clearly shown to have been imposible to maintain uniform fires.

If in the judgment of the committee of judges the firing is inefficiently or improperly done, the test may be terminated at any time, and a repetition of the test refused.

ART. 14. (Pyrometer.) The temperature of the gases of combustion immediately upon entering the chimney flue shall be taken by means of a suitable pyrometer, read at fifteen minutes intervals, and close to the boiler.

ART. 15. (Manometer and Barometer.) The vacuum in the chimney flue shall be taken by means of a water manometer read at fifteen minutes interval. A barometer will be read simultaneously.

ART. 16. (Duration.) Unless otherwise arranged, the tests will last ten hours.

ART. 17. (Economy and Efficiency of the Boiler.) The level of the water in the boiler and the state of the fire must be kept as nearly constant as possible during the whole of the trial.

The weight of the water in the boiler for each one quarter of an inch, on the glass water guage, will be carefully determined and recorded previous to the test, and proper correction for unavoidable changes of level made.

The weight of water fed to the boiler, subject to proper corrections, will be multiplied by its observed thermal value as steam. From this product the thermal units of heat brought in by the feed will be subtracted.

The remainder will be divided by nine hundred and sixty-six and seven-hundredths British thermal units, giving the number of pounds of water evaporated from and at two hundred and twelve degrees Fahrenheit.

This latter quantity will be divided by the weight of coal burned, less weight of dry ashes, giving the number of pounds of water evaporated per pound of combustible. This shall be taken as the measure of the efficiency of the boiler.

The nominal horse-power of the boiler will be deduced by dividing the number of pounds of water evaporated from, and at two hundred and twelve degrees Fahrenheit per hour by thirty.

The evaporative power of the boiler will be determined by dividing the normal horse-power of the boiler by the number of cubic feet of space it occupies.

The space occupied by a boiler and its appurtenances will be regarded as the product of the square feet of floor space occupied by its extreme height in feet.

Methods Used in Testing Boilers.

All the boilers tested by this committee were located in a boiler-house to the north of the exhibition building proper, this boiler-house being open to the weather on the sides. It is probable that the boilers would have shown a higher efficiency, had the boiler-house been entirely enclosed, as the weather was quite cold during part of the tests.

The methods used were, as nearly as possible, the same for each boiler, and are given in detail below.

WATER.

All the water fed to the boilers during the tests was taken from two large tanks, each holding about 2,400 pounds of water, when full. In starting each test, the water-level in the boiler was noted, and all water put into the boiler after the test began was taken from the above-mentioned tanks which were alternately weighed and emptied. At the end of a test, the water-level in the boiler was brought to the same point as at starting, and the amount of water left in the tanks weighed and properly accounted for.

The steam pumps used on all the boiler tests worked very satisfactorily, there being no leaks about either pumps or pipes.

Before testing a boiler, a joint on each water pipe leading to the boiler was broken, and all the pipes disconnected excepting the one feeding from the pump used in testing.

SCALES.

The scales used for weighing feed water and coal were of Riehlé's make, and those used for the calorimeters were partly of Fairbank's and partly of Riehlé's make. All the scales were very accurate and were checked by comparison with Fairbank's standard weights of 50 pounds each.

TEMPERATURE OF FEED WATER.

The temperature of all water fed to the boilers was taken at intervals during the tests, and the mean of these temperatures was taken as the temperature of the feed. The thermometers used were made by J. & H. J. Green, of New York, and were very accurate.

COAL.

The coal used in these tests was purchased at different times and the size was as desired by the exhibitors of the various boilers. All coal was weighed in barrows and allowance made for all that was not used. The coal in all the tests was as it came from the dealer and was slightly wet. In each test a number of barrows full of coal were dried at the temperature of the air, and again weighed, but no appreciable loss of weight was perceptible. In the test of the Root boiler, the floor under the coal was constantly wet from water from the calorimeters used, but the greater part of the coal used was in the same condition as that used in the other tests.

A careful analysis of the coal was made under the direction of Professor Samuel P. Sadtler, from samples taken, from time to time, during the test by Mr. Spangler.

WOOD.

The wood used was such as happened to be most convenient, and was not all of the same kind, but the amount used was so small in comparison with the total amount of fuel, that the same allowance was made in each case for the relative values of coal and wood.

ASHES.

All ashes were weighed dry, and at the end of the test the fire was drawn, and where any unburnt coal came from the furnace, it was credited to the coal account, the remainder was charged to the ash account.

In the case of the Dickson boiler, the ashes were very wet as they were drawn from the ash pan, as the steam blower discharged directly into the ash pan. A number of barrows of ashes were weighed and the percentage of moisture was calculated from the weight after drying, and due allowance made for the same in the ash account.

BAROMETER.

The readings of the barometer were taken from the observations made by the United States Signal Service in Philadelphia, during the time of the tests.

THERMOMETER.

The temperature of the air was taken from the same source and agreed very closely with that taken during the tests.

STEAM PRESSURE.

The steam gauge used on the tests was furnished by the Crosby Steam Gauge and Valve Company. One of these gauges was tested by Thomas Shaw, of Philadelphia, with a mercury column for every five pounds from 0 to 120 pounds, both ascending and descending.

Before and after each test the gauge used on the boilers was carefully compared with this standard, both ascending and descending throughout the range of pressure used on the tests. The gauges were very accurate and agreed as well at the end as at the beginning of the set of tests. Readings were taken at frequent intervals, and the mean of these readings taken as the mean pressure of the steam.

In addition to the Crosby gauge used, an Edson Recording Gauge was attached to each boiler as it was tested, and records made during the entire test. The indications of this gauge were accurate and reliable, but the clockwork required frequent adjusting to keep the recording slip moving at a uniform speed. The alarm attached to the gauge was not used.

TEMPERATURE OF THE STEAM.

A large monitor thermometer was used for indicating the temperature of the steam. It was screwed into the steam space of the boiler, and its indications noted from time to time. These thermometers were a little slow in acting, as there was a considerable body of iron and mercury to change in temperature, but the indications are considered very reliable.

TEMPERATURE OF SMOKE-STACK.

In determining this temperature a monitor thermometer was inserted in the smoke-stack, just back of the damper in the Root, Baldwin, and Harrison boiler, and at the bottom of the smoke-pipe in the Dickson boiler. It was not practicable in all cases to put the thermometer in vertically. In the Harrison test it was vertical; in the Dickson test it was inclined at an angle of about 30 degrees to the vertical; and in

the Root and Baldwin tests, the thermometer was inclined about 10 degrees from the horizontal. The bulb of the thermometer was put as near as possible into the centre of the flue, while the stem projected into the air. The openings into the flue around the thermometer were carefully closed so that no air could enter. Readings were taken as often as practicable from these thermometers, and the mean of the readings taken.

DRAFT IN CHIMNEY.

A number of devices were used for measuring the draft in the chimney. That used on the Root boiler was suggested by Professor Lanza, and was the design of Mr. Fisher, of the Massachusetts Institute of Technology. It consisted of two chambers *a* and *b*, Fig. 1, each covered by a rubber diaphragm *c* and *d*. The interior of the

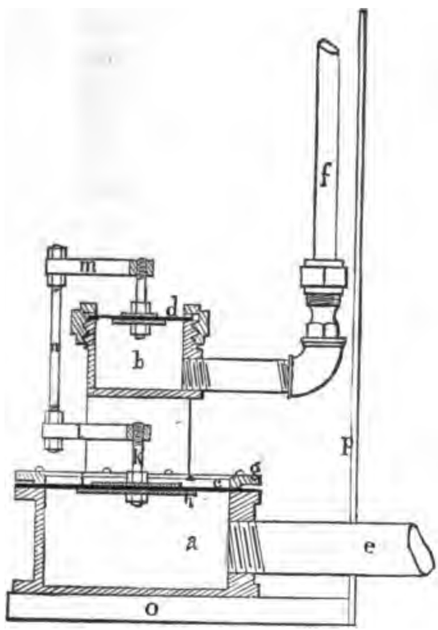

FIG. 1.

chamber *a* is connected with the interior of the chimney by means of a pipe *e*, supplied with a three-way cock so that the interior of *a* can be connected with the chimney or with the air. The interior of *b* is connected by means of a pipe to a vertical glass tube *f*, open at the top.

The chamber *b*, the glass tube *f*, and the connecting pipe are filled with water, the air being entirely excluded. The chamber *b* and all its attachments are carried on the annular ring *g*, which holds the rubber diaphragm of *a* in place. To the centre of the diaphragm *c* two plates *h*, *h*, are attached which support a vertical rod *k*. This rod screws into a cross-head *l*. To the diaphragm of *b* a similar cross-head *m* is attached in the same way, and these two cross-heads are connected by means of two side rods, only one of which, *n*, is shown. The whole apparatus rests on a base board *o*, which carries a vertical piece *p* to which a paper scale graduated in inches is attached. The method of using the apparatus is as follows: The three way cock in *e* being turned so that *a* is in communication with the air, the reading of the scale opposite the head of the water column is noted. The three-way cock is turned so that the inside of *a* is connected with the chimney, and the reading of the top of the column in *f* is again noted, and the difference between the readings is caused by the difference in pressure inside and outside the chimney. This difference divided by the ratio of the areas of the chambers *a* and *b* is the vacuum in the chimney in inches of water.

Comparison was made between this apparatus and the one referred to as the invention of Professor Webb, and the two methods were found substantially to agree.

As the Webb apparatus was more convenient, the one just described was used only on the Root boiler.

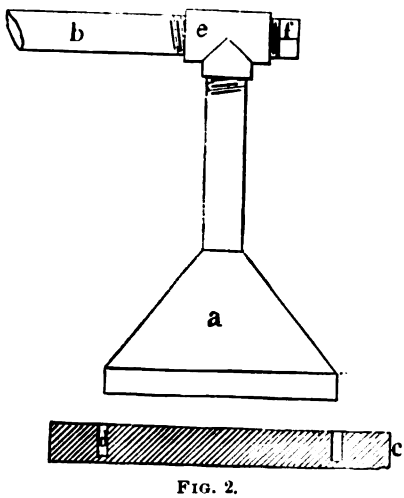

Fig. 2.

In testing the other boilers the following described apparatus, the invention of Professor J. Burkitt Webb, a member of the Committee, was used.

It consisted of an inverted funnel-shaped vessel, *a*, Fig. 2, whose interior is connected through the pipe *b* to the chimney. A piece of gas piping was put into the chimney and connected directly to the pipe *b*. The T *e*, had one end closed by a plug, *f*, so that, if desired, the interior of the funnel *a* could be connected to the air. The funnel *a* and pipe *b* were suspended over a board, *c*, having a circular groove, *d*, cut into its upper face. This board rested on a pair of Fairbanks' scales weighing to ounces. The groove *d* was filled with mercury and the edge of *a* dipped into this mercury.

The method of using the apparatus was as follows: The plug *f* being removed, the scales were balanced; the plug was then replaced, and *b* being connected to the chimney, the scales were balanced again and the difference or loss of weight noted. The loss of weight divided by the area of the mouth of *a* is the loss per square inch, and represents the difference in pressure inside and outside the chimney, and this multiplied by 1·728 gives the corresponding draft in inches of water. The apparatus worked very satisfactorily and the results are very reliable.

QUALITY OF STEAM.

One of the most difficult subjects presented to the Committee was the quality of the steam generated, and we do not think the results obtained are to be implicitly trusted. The data was taken as carefully as could be, but the imperfections of the apparatus were such, that it is a matter of much doubt as to how much reliance can be placed on the results.

There were a number of devices presented to the Committee for use and discussed in their meetings, and the three following described were adopted and used in the tests.

It will be noticed that two different methods of testing the quality of the steam from each boiler were employed, except in the case of the Baldwin boiler, and the results vary so much that no conclusions can be drawn as to the degree of accuracy of either.

While it may be considered that the apparatus giving the most regular results is most to be depended upon, I am satisfied that the conditions in the best boiler are such that the quality of the steam must

be very variable, and it is doubtful whether a mean result is a satisfactory one or not.

The entire subject requires much more investigation than your Committee had the time to undertake.

BARREL CALORIMETER.

One apparatus used for testing the quality of the steam was an ordinary barrel resting on Riehle's scales. A quantity of water was put into the barrel and its weight noted. Just before making the experiment, the temperature of the water was noted. A steam pipe from the boiler led down to within a short distance of the barrel and was covered with felting. To the end of this pipe a short length of hose was attached. Everything being ready for the experiment, the steam was turned on the hose and allowed to blow into the air until apparently dry steam showed at the end of the hose. This end was then put into the barrel and the temperature of the water allowed to rise from 10 to 20 degrees, the water being constantly agitated. The hose was then taken out and the temperature of the water in the barrel noted. The weight was then taken and the pressure of steam during the experiment noted. From this data the quality of the steam was calculated.

In making the calculations, allowance was made for the water equivalent of the barrel used. The barrel being partly filled with water to the level used in the experiments and its temperature noted, a quantity of warm water of known temperature was added and the resulting temperature noted. Knowing the weights of water used, the equivalent of the barrel was found as follows: Multiply the added weight of water by the number of heat units lost by the warm water and divide by the heat units gained by the cold water. This quotient less the weight of cold water in the barrel is the water equivalent of the barrel.

Allowing the water to remain in the barrel for three minutes made no appreciable change in the temperature, showing that there was but little loss from radiation during each experiment, which did not generally last over two minutes.

The following formula was used in making the calculations from data derived while using this apparatus, and an examination of the results will show that they vary surprisingly.

w = weight of cold water plus water equivalent of barrel.
g = heat units corresponding to temperature of cold water, counting from 32°F.
g_1 = heat units corresponding to temperature of the mixture, counting from 32°F.
H = heat units (latent) corresponding to the temperature and pressure of steam.
g_2 = heat units (sensible) corresponding to the temperature and pressure of the steam, counting from 32°F.
w_1 = weight of water and steam added.
φ = water contained in w_1.

$$\varphi = 1 + \frac{1}{H}\left\{(g_2 - g_1) - \frac{w}{w_1}(g_1 - g)\right\}$$

The numerical quantities used in making these calculations were taken from Röntgen's "Thermodynamics" (DuBois' translation), and are substantially the same as other tables derived from the same source, and were used because they were familiar to the young men making the calculations.

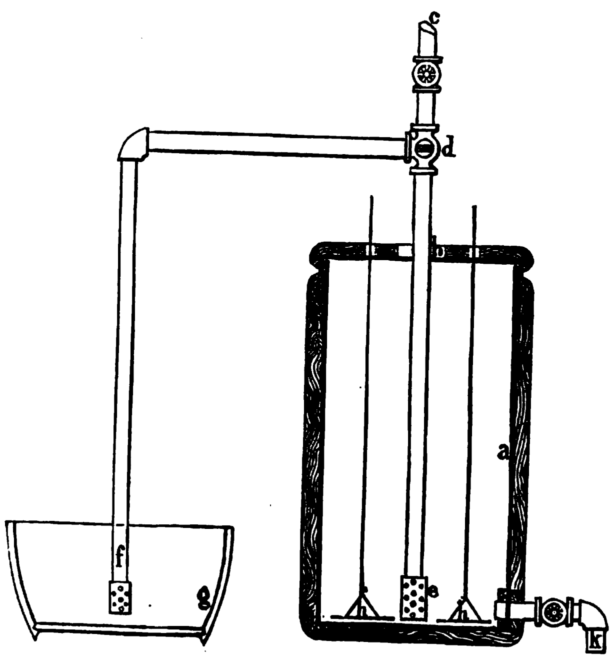

FIG. 3.

The second apparatus used was on the same general principle, and only differed from the first in matters of detail. It is shown in Fig. 3. *a* represents a tin tank, high in proportion to its diameter, and heavily covered with felt and canvas. A tin cover, *b*, fitting over this tank, had an opening in its centre for admitting steam or cold water. *c* is the pipe from the boiler, branching at the three-way cock *d*. One branch goes down into the tank *a*, and has the rose *e* at its lower end. The other branch terminates in the rose *f*, in the tank *g*, which is kept partly filled with water. *k* is the drain-pipe and valve for emptying *a*. The method of operating the calorimeter is as follows: The weight of the tank *a* is taken. It is then partly filled with water, and the weight and temperature is noted. Steam being off the pipe *c*, the three-way cock *d* is turned so that *c* and *f* are in communication. Steam is now turned on *c* and passes into the water in *g*. As soon as the pipe is heated and clear of any condensed water, the three-way cock *d* is turned and the steam allowed to pass into *a*. As soon as a sufficient quantity, say 10 pounds, has passed into *a*, the three-way cock is turned into its original position and steam is shut off *c*. *h*, *h* is an annular perforated plate, having two handles extending through the cover *b*, and is used to thoroughly mix the water in *a*. The temperature is now taken and also the weight of the tank and its contents. The pressure of the steam is noted, and the experiment is ended. The water equivalent of the tank is determined as for the simple barrel, and the calculations are made in the same way as before.

When this and the previous method were used at the same time, the results entirely disagreed.

The third method used was one devised by Mr. Barrus, a member of the Committee on Steam Engines, and was used on both boiler and engine tests.

Fig. 4 is a sketch of the apparatus. It consisted of a wooden vessel, *o*, mounted on a frame at the proper height for use. Inside this vessel were two partitions, so that any water passing from the centre of the vessel, must pass over one and under the second. In the centre of the vessel was a vertical cylinder, *m*, which confined the coldest condensing water to the centre of the apparatus. The condensing water passed down the pipe A, through a valve by which the quantity was regulated, and into the cylinder *m*, out at the bottom of *m*, and out through *c*. The pipe *j* was connected directly to the boiler or steam-pipe from which the steam was to be taken. Below the globe

valve is shown a branch-pipe, forming a gauge siphon. Below the vessel *o*, there is attached to the main pipe a glass water-gauge, *e*, and below this there was a globe valve, *d*, which regulated the discharge of the condensed steam. A short piece of hose was attached and the condensed water was drawn off into two buckets set on accurate pairs of Fairbanks' balances. These buckets were partly filled with cold water and their weights were taken. A quantity of the condensed water was run into one, and before the temperature had risen to 100°F., the hose was moved to the other bucket. The weight of the bucket of warm water was noted and the difference of the weights is the weight of the condensed steam. The bucket was emptied and partly filled with cold water again.

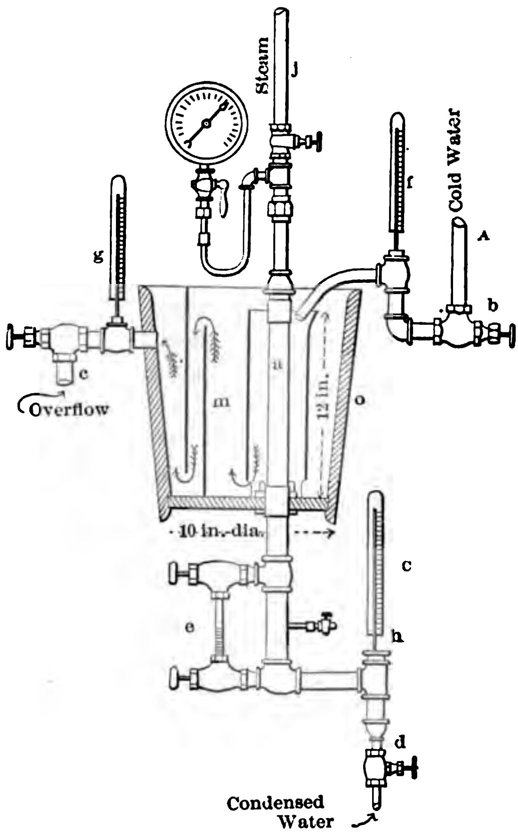

FIG. 4.

The condensing water, after passing *c*, emptied into a tank, which

was supported over two barrels. The water could be directed into either at will. The barrels were weighed empty and full, and the difference taken as the weight of the condensing water.

The temperature of the condensing water was taken at *f*, before going into *o*, and at *g*, after doing its work. The temperature of the condensed water was taken at C, and the temperature of the live steam was taken from the corresponding pressure.

The method of operating the apparatus was as follows:

One barrel under *c* was empty and its weight known, and one bucket was partly filled with cold water and its weight known. Any water passing through *c*, flowed into the unweighed barrel and was allowed to escape through a valve at the bottom. The small hose attached below *d*, discharges into the air. The thermometers and gauge being in place, the valves *b* and *c* were opened wide and water allowed to flow through *m*. The steam-valve was then opened and steam allowed to condense in the pipe, the valve *d* being closed. As soon as the water got to a determined level in the pipe and in *e*, the valve *d* was opened sufficiently to allow as much water to escape as was condensed. The steam valve was opened wide and the supply of cold water was regulated by the valve *b*, until the desired difference of temperature between A and *g* was obtained. The level of the water in *e* should be maintained. This being the case, the water at *c* was turned into the weighed barrel, and the hose from *d* put into the bucket containing the weighed quantity of water.

Readings of the gauge and thermometers were taken every five minutes during the tests.

While the barrel and bucket were filling, the others, which we will call 2, were being prepared. Barrel 2 had the valve at the bottom closed, and was weighed. Bucket 2 was partly filled with water, and weighed.

Bucket 1 being filled, the hose was turned into No. 2, and No. 1 was weighed, emptied, and again filled with cold water, and weighed. The difference between the first two weighings of bucket 1 is the amount of condensed water.

Barrel 1 being filled, the water from *c* was turned into barrel 2. Barrel 1 was weighed, emptied wholly or in part, and was again weighed. The difference between the first two weighings of barrel 1 is the amount of condensing water used. When it is desired to end

the experiment, the barrel and bucket in use should be changed at the same instant, and weighed, and the steam closed off.

One point to be particularly guarded against is the blowing of live steam into the buckets, as in that case the water in the buckets becomes part of the condensing water, and no provision is made for such a contingency.

The calculations were made in the following way: The total amount of condensing and condensed water was determined. The average of the readings of thermometers and gauge was found.

Using the same nomenclature as before, with the following addition and change, the quantity of moisture was determined by the following formula.

g_1 = heat units corresponding to temperature of condensing water after passing through calorimeter, counting from 32°.

g_3 = heat units corresponding to temperature of condensed steam, counting from 32°.

$$\varphi = 1 + \frac{1}{H}\left\{(g_2 - g_3) - \frac{w}{w_1}(g_1 - g)\right\}$$

QUALITY OF GASES OF COMBUSTION.

The apparatus used for making these tests was loaned by Professor Denton, and a sketch of it is given in Fig. 5.

The entire apparatus is mounted on a frame, so that it can easily be moved from place to place. It consists of two glass tubes, a and b, each of about 120 cubic centimetres capacity, joined together by means of the necks d and f connected by a piece of rubber tubing x.

The neck of b extends vertically, and has a stop cock c above the connection with d, and above this the tube is tapered and ground to form a seat for the funnel m. To the bottom of a is attached, by means of a rubber cork, a piece of glass tubing i, to which is attached a piece of rubber tubing, leading to the bottle k. To the bottom of b a similar attachment is made, the only difference being that in the tube g a two-way stop cock h is fitted.

One opening, shown at s, opens downwards, so that the contents of b can be emptied without passing into l. The other opening is directly through the cock, and connects b and l. n is a small barrel having a pipe and valve o for filling it with water, q a pipe and valve for emptying it, and p, a piece of gas piping with cock, the uses of which will be explained.

The method of using the apparatus and making the tests is as follows:

The top of the tube *b* above *c*, is connected with the chimney whose gases are to be analyzed. The tubing connecting *g* and *l* is removed, and *g* and *p* are connected by means of tubing. The bottle, *k*, being filled with water, is raised until the water runs through *d*, *e* being open, and fills *d* to its connection with *b*. The cock *e* is then closed, and *k* is lowered to its original position.

The pipe *o* is connected with a hydrant, *q* is closed, the cock in *p* is opened, *c* is opened, and *h* is put in such a position that *b* and *n* are in communication. Water is allowed to run from the hydrant until *n*, *b* and the pipe connecting with the chimney are filled with water. *o* is then closed, and *q* is opened. The water flows back through *b*, and the chimney gas follows. After sufficient gas has been allowed to pass through *b*, the cocks *c* and *h* are closed.

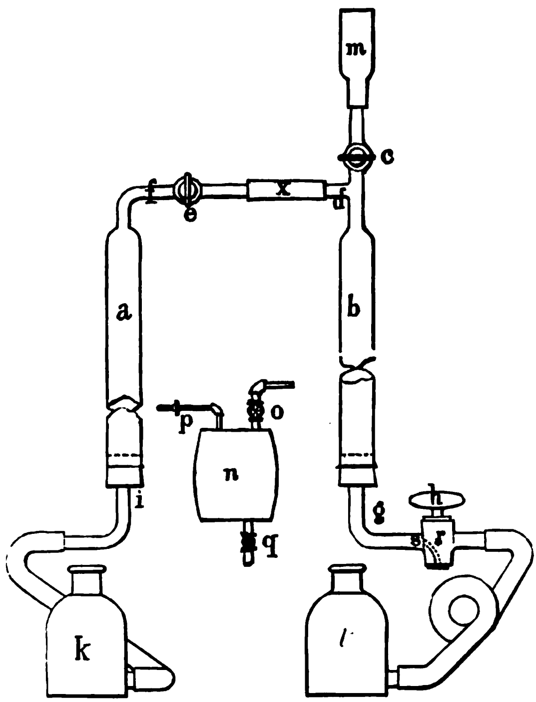

FIG. 5.

The tubing connecting *b* and the chimney, and that connecting *q* and *p*, are taken off, and the bottle *l* is again attached to *g*.

A certain volume of the chimney gas is now confined in *b*, and the apparatus can be moved to any convenient place for further work. The cock *c* being closed, *e* and *h* are opened, and the water is allowed to flow back into *k* until a certain quantity, say 100 cubic centimetres, of the gas is in *a*. The cock *e* is closed and the gas allowed to assume the temperature of the air. The cock *h* is turned so that *b* can be washed out, *c* is opened and the funnel *m* put on; *b* is washed out and filled with clear water from *l*, the cock *h* being again turned and *c* being closed; *k* is now raised until the level of the water in *a* and *k* is the same, and the reading of the scale on *a* is noted.

In the apparatus used, the volume was divided into cubic centimetres, beginning at the cock *e*, but any division into equal volumes would do equally well, and it is not at all necessary that 100 cubic centimetres, or 100 equal parts, should be used in the calculations.

The volume in *a* being noted, the cock *e* is opened, *h* being already so, and the gas is passed back into *b*.

The cock *e* is closed. The funnel *m* is partly filled with caustic potash, the cock *h* is closed and the cock *c* is opened until the greater part of the caustic potash has passed into *b*; *c* is now closed, *e* is opened and the gas again passed into *a*, where its volume is again noted, the level of the liquid in *a* and *k* being the same. As the caustic potash has absorbed all the carbonic acid (CO_2) in the gas, the difference in readings already taken is the volume of carbonic acid in the gas. The The tube *b* is washed out and the process is repeated, using pyrogallic acid in caustic potash, and copper chloride in hydrochloric acid. The first of these removes the oxygen, and the last the carbonic oxide (CO).

To determine the amount of air present per pound of carbon, add together the volume of O and CO and twice the volume of CO_2. Divide by the sum of the volumes of CO and CO_2, and $\frac{4}{3}$ the quotient is the weight of oxygen present per pound of carbon. This result divided by ·23 is the weight of air used per pound of carbon, and this result divided by the percentage of carbon in the coal is the weight of air used per pound of coal.

MAKING THE TESTS.

In making the boiler tests, steam was first raised to the working pressure in each boiler, and the fires were then hauled. All wood and

coal used thereafter was weighed, and at the end of the test the fire was hauled, and any unburnt coal credited to the boiler.

Water in the boiler was carried as nearly as possible at one height, and at the end of the test was brought back to the same level as at the beginning of the test.

DURATION OF THE TESTS.

Each test lasted 36 hours, except in the case of the Baldwin boiler, where the test was terminated at the end of 24 hours.

The following are the results of the different tests, together with the results derived from the observed data.

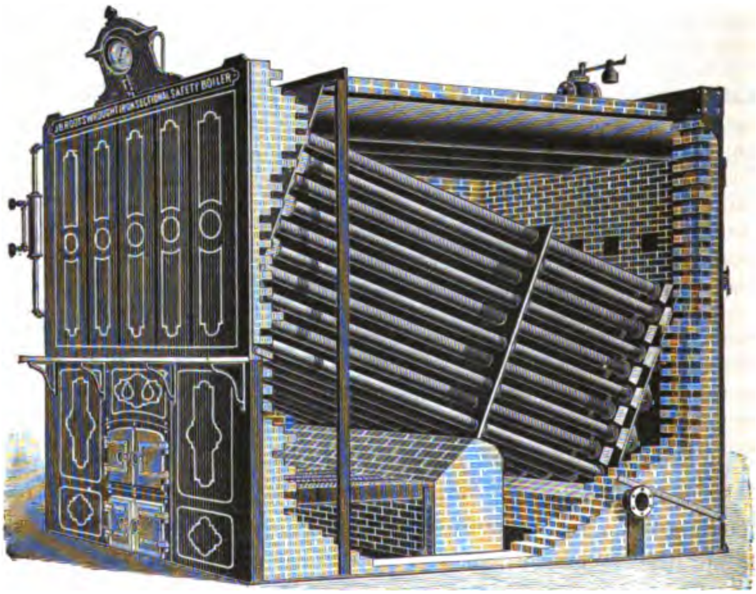

FIG. 6.

ROOT BOILER.

Before testing this boiler, (Fig. 6,) the back was boarded up. No other preparations were made for the test except cleaning the boiler the day before.

Ordinary care was taken with the fires, and the boiler was treated as in ordinary use.

Fires were started at 2.15 A.M., October 2, and as soon as the pressure of steam to be carried was reached, fires were hauled, and again

started at 3.25 A.M., with a weighed quantity of wood and coal. At 3.25 P.M., October 3, fires were hauled and the test concluded.

BOILER MADE BY ABENROTH & ROOT MANUFACTURING COMPANY.

Rated horse-power		150.
Area heating surface.		
Having water on one side	=	1440 square feet.
Having steam on one side	=	360 square feet.
Total	=	1800 square feet.
Area of grate	=	50 square feet.
Steam space (approximate)	=	76·5 cubic feet.
Height of smoke stack	=	44 feet 6 inches.
Size of stack	=	30 by 30 inches.
Time of test	=	36 hours.
Water evaporated in boiler	=	134937·3 pounds.
Mean temperature of feed water	=	71·6 degrees F.
Total weight of wood used	=	291·5 pounds.
Total weight of coal used	=	18021·5 pounds.
Total weight of ashes	=	2666·75 pounds.
Percentage of carbon in coal	=	75·52.
Mean temperature of air during test	=	57·0 degrees F.
Mean barometer	=	30·323 inches.
Mean pressure in boiler	=	91·41 pounds.
Mean temperature of steam	=	341·32 degrees F.
Mean temperature of smoke stack	=	369·92 degrees F.
Mean draft in chimney in inches of water	=	·7.
Time during which blower was in use	=	16 hours.
Mean pressure in boiler pipe	=	1·16 inches.
Mean area of blower pipe open	=	49·93 square inches.
Mean pounds of air per pound of carbon	=	16·83.

The quality of steam from the calorimeter tests has not been determined, as the want of agreement in the two sets of tests make the results unsatisfactory.

The following gives the number of heat units in one pound of steam by both the apparatus shown in Fig. 3, and by using the plain barrel, and I would recommend that these results be entirely rejected, and the quality of the steam taken as from the temperature, which would make in this case 9·37° superheating.

The following table is from the calorimeter tests:

Time.	Total heat in 1 pound of steam from 32°F.	
	Apparatus of Fig. 3.	Barrel.
October 2, 2.57 P.M	1335·4	1185·5
" 3.57 "	1323·2	1290·1
" 4.57 "	1306·7	1272·5
" 5.57 "	1309·7	1192·8
" 7.57 "	1406·3	1367·8
" 9.57 "	1247·0	1485·5
" 11.57 "	1270·5	1047·2
October 3, 1.57 A.M	1282·5	1396·8
" 2.57 "	1344·6	1003·2
" 3.57 "	1285·7	1142·8
" 4.57 "	1281·8	1343·3
" 5 57 "	1335·0	1205·1
" 6.57 "	1250·4	1093·2
" 7.57 "	1216·4	1158·1
" 9.57 "	1256·4	1329·7
" 12.57 P.M	1268·8	1179·9
" 1.57 "	1296·7	1206·0
" 2.57 "	1313·9	1177·3

Calling one pound of wood equal to ·24 pound of coal in heating effect, the total equivalent weight of coal used is 70 + 18021·5 = 18091·5 pounds.

The percentage of ash is 14·74, while as shown from the analysis made it is 14·52 per cent.

The heat giving power of the fuel is determined as follows: There being 75·52 per cent. of carbon, and 2·18 per cent. of hydrogen exclusive of water, the equivalent percentage of carbon is $75{\cdot}52 + 4{\cdot}28 \times 2{\cdot}18 = 84{\cdot}85$ per cent., and the amount of carbon equivalent to the 18091·5 pounds of coal is $\cdot 8485 \times 18091{\cdot}5 = 15350{\cdot}64$ pounds of carbon.

To change one pound of water at 71·6° F. to steam at 341·32° F. requires $1186{\cdot}04 - 39{\cdot}6 = 1146{\cdot}44$ heat units. As it takes 966·07 heat units to change one pound of water at 212° F. to steam at 212; one pound of water from 71·6° to one pound of steam at 341·32° requires the same amount of heat as 1·1867 pounds from and at 212°.

Pounds of water evaporated per hour under the conditions......	= 3748·26
Pounds of water evaporated per hour from and at 212° F..........	= 4448·0
Pounds of coal used per hour..	= 468·87
Equivalent pounds of carbon used per hour.............................	= 426·41
Horse-power of boiler (on the basis of 30 pounds of water from and at 212° per horse-power)...	= 148·27
Pounds of water evaporated per pound of coal under the conditions..	= 7·9942
Pounds of water evaporated per pound of coal from and at 212°..	= 9·4866
Pounds of water evaporated per equivalent pound of carbon under the conditions..	= 8·7903
Pounds of water evaporated per equivalent pound of carbon from and at 212° F...	= 10·4313

Amount of air used in furnace per pound of coal $= \frac{16 \cdot 83}{\cdot 7552} = 22 \cdot 29$ pounds.

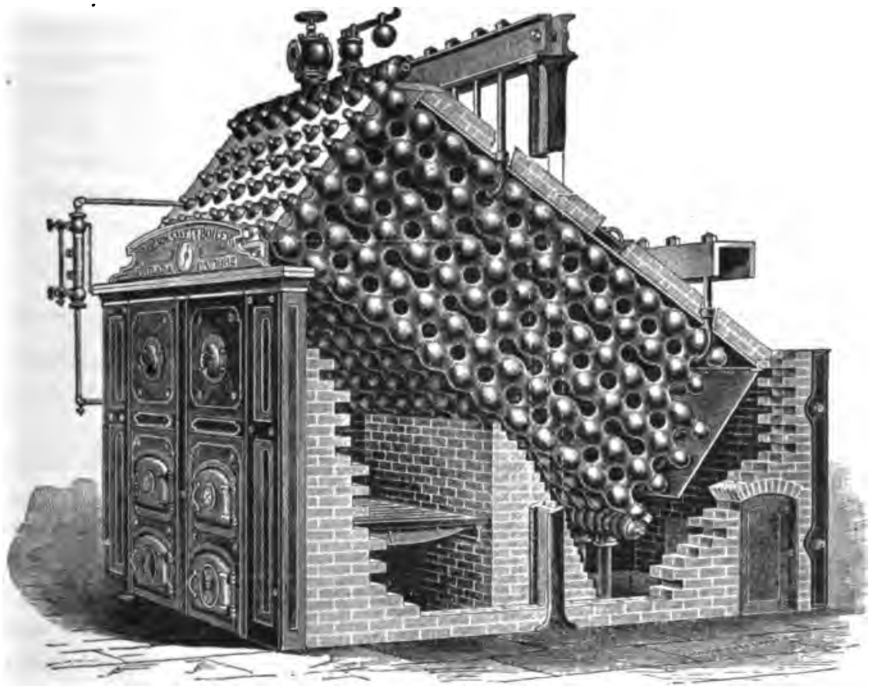

FIG. 7.

HARRISON BOILER.

The test began at 11.25 A. M., October 9, 1884, in the same manner as described for the Root test. At 12.57 P. M., October 10, cleaned boiler by means of steam nozzle, and at 11.25 P. M., October 10, fires were hauled and the test concluded.

Rating of boilers, manufacturers	100 horse-power
Water heating surface	948·54 sq. feet.
Steam " "	348·96 "
Total " "	1297·50 "
Steam room in boiler	29·8 cubic feet.
Grate surface	35·13 sq. feet.
Height of stack from ground	44 feet 6 in.
Size of pipe	30 × 30.
Water in boiler to steaming level	4878 pounds.
Time of test	36 hours.
Total weight of water evaporated in boiler	92606·75 pounds.
Mean temperature of water	68·77° F.
Total weight of wood used	348·5 pounds.
" " coal "	11725·75 "
" " ashes	1475·75 "
Percentage of carbon in coal	75·21
" " hydrogen "	1·82
Mean temperature of air during test	57·84° F.
Mean barometer	30·253 inches.
Mean pressure in boiler	95·83 pounds.
Mean temperature of steam	337·16° F.
Mean temperature of smoke-pipe	411·03° F.
Mean draft in chimney	·24 in. water.

Mean pounds of air per pound of carbon = 15·09.

QUALITY OF STEAM.

The quality of the steam was determined both by the Barrus calorimeter and the apparatus shown in Fig. 3, with the following results:

BARRUS CALORIMETER.

From 5.40 P. M. to 7.40 P. M., October 9...steam contains 7·4 per ct. water.
From 7.40 P. M. to 9.40 P. M., October 9..... " " 7·0 " "
From 9.40 P. M. to 11.40 P. M., October 9..... " superheated 63°
From 1.25 A. M. to 4.20 A. M., October 10...steam contains 3·4 per ct. water.
From 4.20 A. M. to 11.30 A. M., October 10.. " " 3·5 " "
From 11.30 A. M. to 1.25 P. M., October 10.. " " 2·1 " "
From 2.40 P. M. to 4.45 P. M., October 10... " " 0·11 " "
From 4.50 P. M. to 6.45 P. M., October 10.... " " 2·8 " "
From 6.50 P. M. to 8.55 P. M., October 10... " " 4·5 " "
From 9.45 P. M. to 11.20 P. M., October 10.. " superheated 168°.

From the apparatus shown in Fig. 3, we have the following results:

1.00 P. M., October 9..........................steam superheated 68°.
2.00 P. M., October 9 (a)...................... " " beyond limits of tables.
4.00 P. M., October 9.......................... " contains 13·1 per cent. water.
5.00 P. M., October 9.......................... " " 5·3 " "
6.00, 9 00, 10.00, 11.00, 12.00..................same as (a).

7.00.................... ....steam contains 30·7 per cent. water.
1.00 A. M., October 10..............................same as (a).
3.00 A. M., October 10..............................steam superheated 57°.
5.00, 6.00 A. M., October 10....................same as (a).
7.00 A. M., October 10..............................steam contains 7·7 per cent. water.
8.00 A. M., October 10.............................. " superheated 57°.
9.00, 10.00, 11.00, 12.00, October 10. ....same as (a).
1.00 P. M., October 10..............................same as (a).
3.00, 4.00, 5.00, 6.00, October 10..................same as (a).
7.00 P. M , October 10..............................steam superheated 70°.
9.00, 10.00 and 11.00 P. M., October 10......same as (a).

While the results given from the Barrus calorimeter show a reasonable agreement, it is doubtful whether the results are a fair measure of the quality of the steam produced, as the thermometer in the steam space shows 337·16° F., while the temperature corresponding to the steam pressure 95·83 pounds is 334·93° F. The difference, or 2·23°, shows that the average quality of the steam was dry or superheated 2·23° F., and in the succeeding deductions this value will be taken in calculating the relative weight of water evaporated per pound of coal.

As before, assuming that one pound of wood = ·24 pounds of coal, the total equivalent weight of coal used is $348{\cdot}5 \times {\cdot}24 + 11725{\cdot}75 = 11809{\cdot}39$ pounds. The percentage of ash is $\frac{1475{\cdot}75}{11809{\cdot}39} = 12{\cdot}5$ per cent., while the analysis made shows 14·03 per cent.

The heat giving power of the fuel is determined as follows: there being 75·21 per cent. of carbon and 1·82 per cent. of hydrogen, exclusive of water, the equivalent percentage of carbon is $75{\cdot}21 + 1{\cdot}82 \times 4{\cdot}28 = 83{\cdot}00$ per cent., and the equivalent amount of carbon in the 11809·39 pounds of coal is $11809{\cdot}39 \times {\cdot}83 = 9801{\cdot}79$ pounds.

To change one pound of water at 68·77° F. into steam at 337·16° F. requires $1184{\cdot}77 - 36{\cdot}77 = 1148{\cdot}00$ heat units. As it takes 966·07 heat units to change one pound of water at 212° into steam, at 212°, one pound of water from 68·77° to steam at 337·16° requires the same amount of heat as 1·1883 pounds of water from and at 212°.

Pounds of water evaporated per hour under the conditions.......	= 2572·41
Pounds of water evaporated per hour from and at 212°..............	= 3056·79
Pounds of coal used per hour........	= 328·04
Equivalent pounds of carbon used per hour.................	= 272·27
Horse-power of boiler on the basis of 30 pounds of water from and at 212° per horse-power..	= 101·89

Pounds of water evaporated per pound of coal underthe conditions .... = 7·8417

Pounds of water evaporated per pound of coal from and at 212°.. = 9·3183

Pounds of water evaporated per equivalent pound of carbon under the conditions .... = 9·4480

Pounds of water evaporated per equivalent pound of carbon from and at 212°.. .... = 11·2270

Amount of air used in furnace per pound of coal $\frac{15{\cdot}09}{{\cdot}7521}=20{\cdot}06$ pounds.

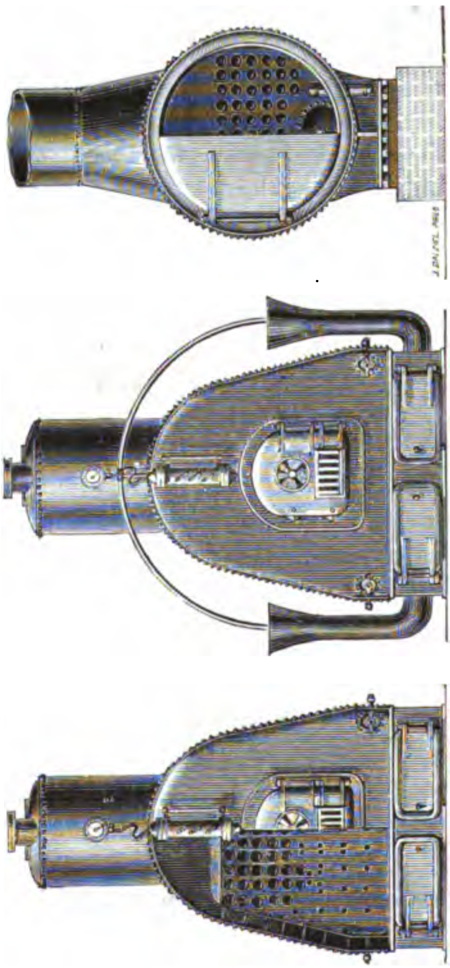

Fig. 8.

DICKSON BOILER.

This boiler, Figs. 8 and 9, is manufactured by the Dickson Manu-

facturing Company, of Scranton, Pennsylvania. It is a horizontal tubular boiler having 68, 3 inch tubes, each 15 feet long. It has a spread fire box wider at the top than at the bottom. The grate used was of the Howe pattern, 6 feet 6 inches by 4 feet 10 inches. The shell is cylindrical 50 inches in diameter and is 34½ feet long. The steam dome is 30 inches by 30 inches.

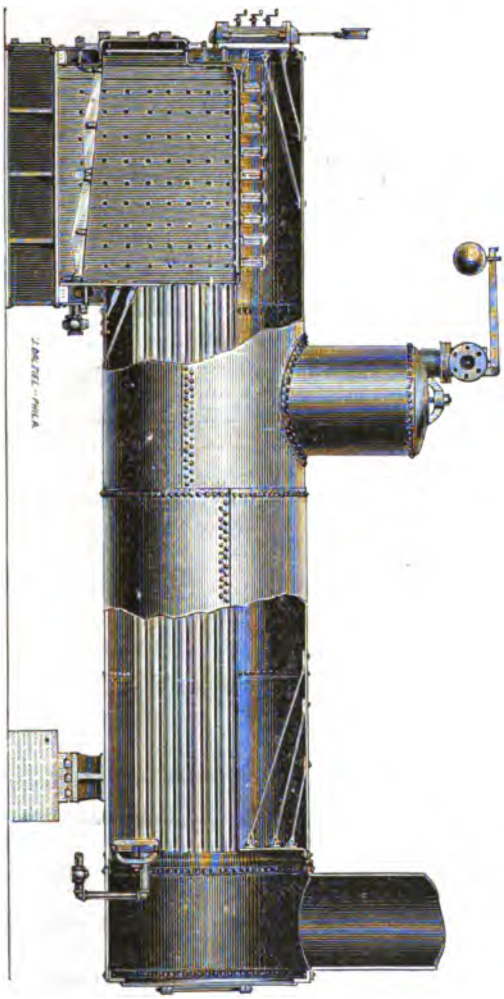

FIG. 9.

Rating of boiler, manufacturers = 76 horse-power. Before beginning this test the boiler was thoroughly protected by means of a one-inch layer of felt over the entire boiler, excepting the front head. The

test began at 6.31 P. M., October 13, 1884, and ended at 6.31 A. M., October 15.

The boiler was designed to burn culm, but as none could be procured in time for the test, screenings from pea coal were used instead.

Water heating surface	=	841· sq. feet.
Steam " "	=	2·5 "
Total " "	=	843·5 "
Grate surface	=	31·41 "
Steam space in boiler	=	67 cubic ft.
Weight of water in boiler at ordinary standing level	=	10200 pounds.
Time of test	=	36 hours.
Total weight of water evaporated in boilers	=	137152·75 pounds.
Water used per hour to run jet	=	472·5 "
Mean temperature of water	=	67·17° F.
Total weight of wood used	=	232·5 pounds.
" " coal "	=	20026 50 "
" " ashes (net)	=	5048·37 "
Percentage of carbon in the coal	=	72·87
" hydrogen (exclusive of water)	=	2·53
Mean temperature of air	=	50·26° F.
Mean barometer	=	30·299 inches.
Mean pressure in boiler	=	83·54 pounds.
Mean temperature of steam	=	326·19° F.
Mean temperature of smoke-stack	=	422·72° F.
Mean draft in chimney	=	·15 inches.
Mean air per pound of carbon	=	13·66 pounds.

QUALITY OF STEAM.

The quality of the steam was determined both by the Barrus calorimeter and by the apparatus shown in Fig. 3, with the following results:

BARRUS CALORIMETER.

From 7.20 P. M., October 13 to 11.20 A. M., October 14, steam contains 0·78 per cent. water.

From 1.20 A. M. to 3.20 A. M., October 14, steam contains 2·7 per cent. water.

From 3.20 A. M. to 5.20 A. M., October 14, steam contains 1·9 per cent. water.

From 5.20 A. M. to 12.00 noon, October 14, steam contains 2·5 per cent. water.

From 12.00 noon to 2.00 P. M., October 14, steam contains 7·6 per cent. water.

From 2.00 P. M. to 4.00 P. M., October 14, steam superheated 22°.

From 4.00 P. M. to 6.00 P. M., October 14, steam superheated 7°.
From 6.00 P. M. to 8.00 P. M., October 14, steam contains 1·2 per cent. water.
From 8.00 P. M. to 10.00 P. M., October 14, steam contains 3·8 per cent. water.
From 10.00 P. M. to 12.00 midnight, October 14, steam contains 2·6 per cent. water.
From 10.00 midnight to 2.00 A. M., October 15, steam contains 0·8 per cent. water.
From 2.00 A. M., October 15 to 4.00 A. M., October 15, steam contains 1·7 per cent. water.
From 4.00 A. M., October 15 to 6.00 A. M., October 15, steam contains 1·2 per cent. of water.

The results from the apparatus shown in Fig. 3 were totally unreliable, giving in every case highly superheated steam of 400° or over.

As the temperature of the steam almost exactly corresponds with the temperature corresponding to the pressure, it is evident that the steam must have been either saturated or wet, and taking the results from the Barrus apparatus as correct, we have for a mean 1·55 per cent. of moisture in the steam, and this value will be taken in the succeeding deductions.

As before, assuming that one pound of wood = ·24 pounds of coal, the total equivalent weight of coal used is $232{\cdot}5 \times {\cdot}24 + 20026{\cdot}50 = 20082{\cdot}3$ pounds.

The percentage of ash is $\frac{5048{\cdot}37}{20082{\cdot}3} = 25{\cdot}1$ per cent., while the analysis of the coal made shows but 10·39 per cent. This discrepancy may be accounted for in the following way: the coal used was siftings from pea coal, considerable of which fell through the grate partly burned, and as the ashes were continually wet from the steam jet, no attempt was made to burn the refuse a second time, as the loss from the wet ashes would probably be more than the gain from more perfect combustion.

The equivalent weight of carbon used was determined as in the case of the preceding boilers. The percentage of carbon being 72·87 and of hydrogen (exclusive of water) 2·53, the equivalent percentage of carbon is $72{\cdot}87 + 4{\cdot}28 \times 2{\cdot}53 = 83{\cdot}70$; and the equivalent amount of carbon in the 20082·3 pounds of coal is 16808·89 pounds.

To change one pound of water at 67·17° into steam 83·54 pounds pressure and containing 1·55 per cent. of moisture requires 1167·78

— 35·17 = 1132·61 heat units. As it takes 966·07 heat units to change one pound of water at 212° into dry steam at 212°, one pound of water under the conditions of this test requires the same amount of heat as 1·1724 pounds of water from and at 212°.

As the total weight of water evaporated is 137152·75 pounds, and as 472·5 pounds of water are used per hour to run the jet, the amount of water available for use outside the boiler, or the proper quantity of water which should be credited to the boiler is 137152·75 — 36 × 472·5 = 135451·75 pounds.

Pounds of water evaporated per hour under the conditions.......	= 3762·55
Pounds of water evaporated per hour from and at 212°..............	= 4411·21
Pounds of coal used per hour..	= 557·84
Equivalent pounds of carbon used per hour..............................	= 466·91
Horse-power of boiler (on basis of 30 pounds of water from and at 212° per horse-power)..	= 147·04
Pounds of water evaporated per pound of coal under the conditions..	= 6.7449
Pounds of water evaporated per pound of coal from and at 212°	= 7·9076
Pounds of water evaporated per equivalent pound of carbon, under the conditions..	= 8·0584
Pounds of water evaporated per equivalent pound of carbon from and at 212°..	= 9·4477

Amount of air used in furnace per pound of coal $= \frac{13·66}{·7287} =$ 18·74 pounds.

BALDWIN BOILER.

An attempt to test this boiler was made on September 29, 1884, and after continuing for 24 hours, the fires became very low because of the coal having so much clinker, requiring that the fires should be constantly cleaned, and the test was stopped.

At the request of the company exhibiting the boiler, a second test was made beginning at 1.19 P. M., October 24, 1884, and ending at 1.19 P. M., October 25, 1884, and the results of this test alone are given in this report.

This boiler was made by the Baldwin locomotive works. It is a horizontal cylindrical flue boiler, sixteen feet long, of 54 inches diameter, and having 4-inch flues. The bottom of the boiler was set 34 inches above the grate.

Over the boiler is placed a steam drum twenty-four inches in diameter and eight feet long, connected to the boiler by means of one neck 12 inches in diameter and 10 inches long.

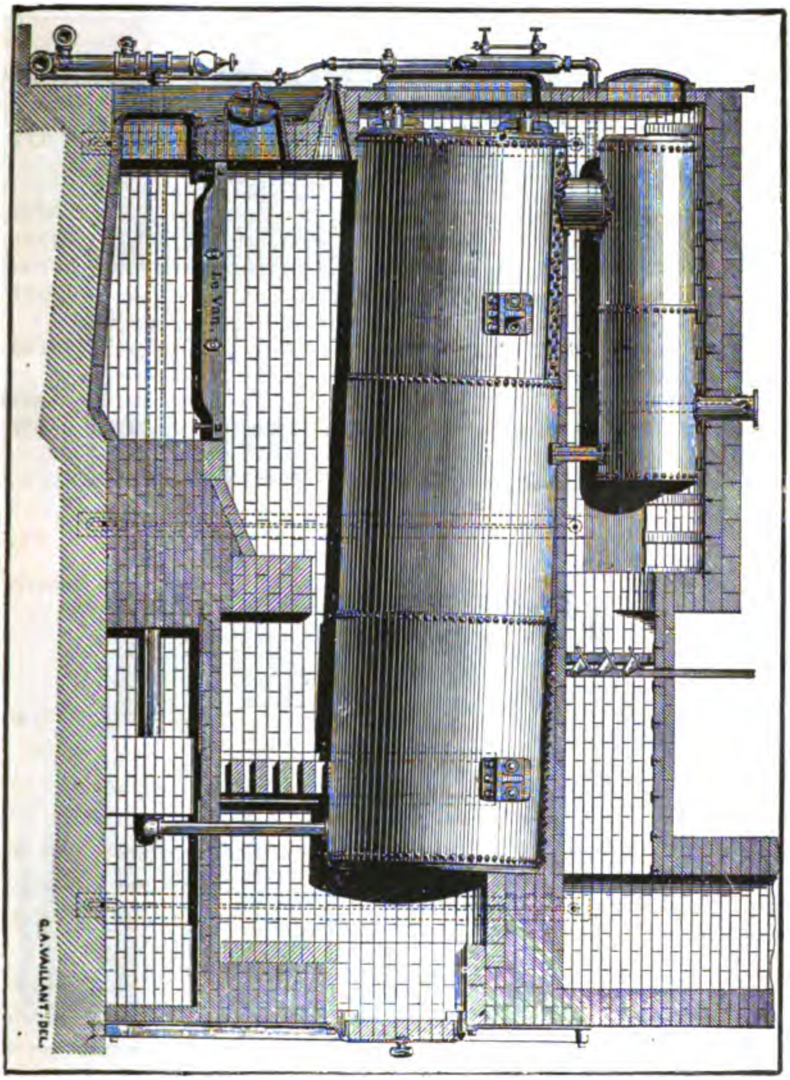

FIG. 10.

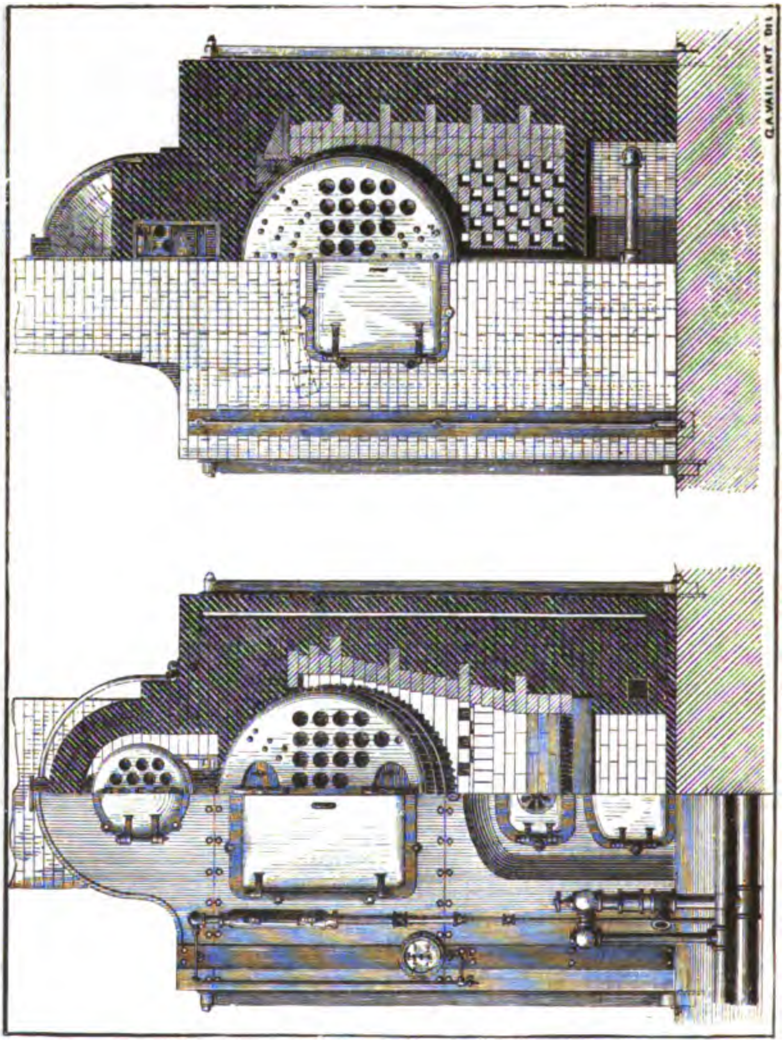

Fig. 11.

Rating of boiler	50 horse-power.
Grate surface	21 square feet.
Heating surface, total	799·62 sq. feet.
" " wetted	663·31 sq. feet.
" " steam	136·31 sq. feet.
Grate 42 inches by 72 inches.	
Chimney 30 inches by 30 inches.	
Height of chimney	44 feet 6 inches.
Time of test	24 hours.
Total weight of water evaporated in boiler	38108·0 pounds.
Mean temperature of water =	59·91° F.
Total weight of wood used =	191·5 pounds.
Total weight of coal used =	6031·0 "
Total weight of ashes =	654·25 "
Percentage of carbon in coal =	80·22
Percentage of hydrogen (exclusive of water) =	2·53
Mean temperature of air during test =	45·25° F.
Mean barometer =	30·274 inches.
Mean pressure in boiler =	98·71 pounds.
Mean temperature of steam =	343·78° F.
Mean temperature of smoke stack =	346·85° F.
Mean draft in chimney =	·243 inches.
Mean air per pound of carbon =	16·24 pounds.

QUALITY OF STEAM.

The quality of the steam was determined only by the Barrus calorimeter with the following results:

From 2.50 P. M., October 24, to 4.20 P. M. October 24, steam contains 0·78 per cent. water.

From 4.20 P. M., October 24, to 6.20 P. M., October 24, steam contains 1·8 per cent. water.

From 6.20 P. M., October 24, to 8.20 P. M., October 24, steam contains 1·9 per cent. water.

From 8.20 P. M., October 24, to 10.20 P. M., October 24, steam is dry.

From 10.20 P. M., October 24, to 12.20 A. M., October 25, steam contains 2·8 per cent. water.

From 2.20 A. M., October 25, to 4.20 A. M., October 25, superheated 174°.

From 4.20 A. M., October 25, to 6.20 A. M., October 25, contains 3·9 per cent. water.

From 8.40 A. M., October 25, to 12.20 P. M., October 25, contains 23.5 per cent. water.

The mean of these results is 6·95 per cent. of moisture in the steam. The temperature of the steam by thermometer is 343·78° F., and the temperature corresponding to the pressure 98·71 pounds per gauge is 336·83° F., and the average quality of the steam from the temperature

is 6·95° superheated. Assuming that this latter value is more correct than the one given by the Barrus calorimeter, this value will be used in the following deductions.

As before, assuming that one pound of wood = ·24 pounds of coal, the total equivalent weight of coal used is $6031 + 191 \cdot 5 \times \cdot 24 = 6076 \cdot 96$ pounds.

The percentage of ash is $\frac{654.25}{6076 \cdot 96} = 10 \cdot 76$ per cent., while the analysis made shows 10·39 per cent.

The equivalent weight of carbon used was determined as in the cases of the preceding boilers. The percentage of carbon being 80·22, and of hydrogen (exclusive of water) 2·53 per cent, the equivalent percentage of carbon is $80 \cdot 22 + 4 \cdot 28 \times 2 \cdot 53 = 91 \cdot 05$ per cent., and the equivalent amount of carbon in 6076·96 pounds of coal is = 5533·07 pounds.

To change one pound of water at 59·91° into steam of 98·71 pounds pressure and 6·95° superheated, requires $1186 \cdot 791 - 27 \cdot 91 = 1158 \cdot 881$ heat units. As it takes 966·07 heat units to change one pound of water at 212° into steam at 212°, one pound of water under the conditions of this test requires the same amount of heat as 1·1996 pounds of water from and at 212°.

Pounds of water evaporated per hour, under the conditions	=	1587·83
Pounds of water evaporated per hour, from and at 212°	=	1904·76
Pounds of coal used per hour	=	253·21
Equivalent pounds of carbon used per hour	=	230·54
Horse-power of the boiler (on the basis of 30 pounds of water from and at 212° per hour, horse-power)	=	63·49
Pounds of water evaporated per pound of coal, under the conditions	=	6·2708
Pounds of water evaporated per pound of coal from and at 212°	=	7·5224
Pounds of water evaporated per equivalent pound of carbon, under the conditions		6·8874
Pounds of water evaporated per equivalent pound of carbon, from and at 212°		8·2621
Amount of air used in the furnace per pound of coal		20.24 lbs.

Resumé of Results obtained in Boiler Tests.

Name of Boiler on Trial.	Root.	Harrison.	Dickson.	Baldwin.
Date of Trial.	Oct. 2, 1884.	Oct. 9.	Oct. 13.	Oct. 24.
Duration of trial in hours	36	36	36	24
Rated horse-power by makers	150	100	76	50
Developed horse-power in test assuming 30 pounds of water from and at 212 degrees per horse-power	148·27	101·89	147·04	63·49
Water heating surface in square feet	1440	948·54	841	663·31
Steam heating surface in square feet	360	348·96	2·50	136·31
Total heating surface in square feet	1800	1297·5	843·50	799·62
Grate surface in square feet	50	35·13	31·41	21
Ratio of grate to heating surface	1 : 36	1 : 37	1 : 26·8	1 : 38
Height of chimney, in feet, from grate	44·5	44·5	28·6	44·5
Average steam pressure in pounds per square inch	91·41	95·83	83·54	98·71
Barometer in inches	30·323	30·253	30·299	30·274
TEMPERATURES, FAHRENHEIT.				
Average temperature of the air (Fah.)	57	57·84	50·26	45·25
Average temp. of the steam in boilers	341·32	337·16	326·19	343·78
Temperature corresponding to average boiler pressure	331·95	334·93	326·36	336·83
Average temperature of the chimney	369·92	411·03	422·72	346·85
Average temperature of the feed-water	71·6	68·77	67·17	59·91

Resumé of Results obtained in Boiler Tests.—Continued.

Name of Boiler on Trial.	Root.	Harrison.	Dickson.	Baldwin
Date of Trial.	Oct. 2, 1884,	Oct. 9.	Oct. 13.	Oct. 24.
COAL AND ASHES.				
Pounds of wood used	291·5	348·5	232·5	191·5
Pounds of coal used	18021·5	11725·75	20026·5	6031
Pounds of coal and wood, including value of latter	18091·5	11809·39	20082·3	6076·96
Pounds of ashes	2666·75	1475·75	5048·37	654·25
Pounds of carbon	15350·64	9801·79	16808·8	5533·07
Pounds of carbon per hour	426·41	272·27	466·9	230·54
Pounds of coal per hour	468·87	328·04	557·84	253·21
WATER.				
Pounds of water feed in the boiler at average temperature above given	134937·3	92806·75	137152·75	38108
Pounds of water evaporated per hour from and at 212°	4448	3056·79	4411·21	1587·83
Pounds of water evaporated per pound of coal	7·99	7·84	6·75	6·27
Pounds of water evaporated per pound of carbon from and at 212°	10·43	11·23	9·45	8·26
Quality of steam by thermometer, or amount of superheating	9·37	2·23	....	6·95
Percentage of moisture	....	....	1·55	....
RATE OF COMBUSTION.				
Pounds of coal burnt per square foot of grate per hour	10	9·3	18	12
Pounds of water per square foot of grate per hour	87	89	140	76
Pounds of water per square foot of heating surface per hour	2·3	2·5	5.2	2
DRAFT.	Blower.	Natural.	Steam Jet.	Natural.
Mean draft in chimney in inches	0·7	·24	·15	.43
Steam room in boiler in cubic feet	7·65 ap.	29·8	67	....

At the meeting of the Examiners of Section X, held at the Franklin Institute, March 23, 1885, the following resolution was adopted: *

Resolved, That the report of Mr. Spangler be adopted as rendered, and that the same be published in its entirety, with the addition of a tabulated resumé of the results. That the committee refrain from criticism of the boilers as prescribed by the Code, excepting upon the points of economy of fuel and evaporated efficiency, as contained in report adopted. That all accuracy of the calorimetrical measurements be disclaimed, but all data referring thereto be printed, as evidence of work performed in the attempt to obtain reliable results.

WM. D. MARKS,
W. BARNET LE VAN,
C. CHABOT,
A. B. WYCKOFF.

ARTHUR L. CHURCH,
FRED'K GRAFF,
CHAS. E. RONALDSON,
OTTO C. WOLF,
Committee present.

Members of Section X.—Gould H. Bull, C. Chabot, R. E. Crawford, J. E. Denton, Charles H. Fisher, Carl Hering, Washington Jones, Gaetano Lanza, W. Barnet Le Van, William Ludlow, William D. Marks, O. E. Michaelis, John Milliss, John W. Nystrom, T. W. Rae, Charles E. Ronaldson, H. W. Spangler, Otto C. Wolf, A. B. Wyckoff.

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* This report has, according to the directions of the Board of Managers of the Franklin Institute, been edited and supervised by the Committee appointed for that purpose. The language of this resolution must not be interpreted to imply that any exception was made to the mode of printing the reports.

PERSIFOR FRAZER,
WM. H. WAHL,
Executive Committee of Editing Committee.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XI.

(SECTION I, CLASS VI OF THE CATALOGUE.)

STEAM ENGINES.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, FEBRUARY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,
CHARLES BULLOCK,
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COLEMAN SELLERS,
WILLIAM H. WAHL.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XI.—STEAM ENGINES.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of Examiners of Section XI, on "Steam Engines."

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, November, 1885.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—I herewith hand you the report of Section XI, on "Steam Engines."

Respectfully,

WM. D. MARKS.
Chairman Section XI.

REPORT OF EXAMINERS. SECTION XI. STEAM ENGINES.

Code of the Quantitative Tests Proposed for the Steam Engines, at the International Electrical Exhibition of 1884, of the FRANKLIN INSTITUTE, *of the State of Pennsylvania.*

SPECIAL NOTICE.

Parties exhibiting engines who may desire quantitative tests made of them, must make formal application for such tests before July 15, 1884.

Engines can be exhibited, but will not be tested unless formal application and agreement to the code are completed within the specified time.

Parties desiring to have tests made of their engines, can have them made by so signifying and by subscribing to and fulfilling the conditions of the Code.

All tests will be quantitative, and will not be abridged, save by special agreement with the judges.

Tests of regularity of speed will, however, be made independently of other measurements.

The Committee reserves the right to limit the number of engines tested, and to elect which engines shall be tested, if time will not permit complete tests of all.

Competitive tests will not be made, save on the joint application of the two or more parties desiring them, who must agree on the rating of the various points of the engines (See Article 9) previous to the tests, and subscribe in the Code, agreeing to abide by the decision of the Judges without appeal.

SECTION I.

CONDITIONS OF EXHIBITION AND TEST.

ARTICLE 1. Cylinders.

The cylinders of the engines entered may be of any capacity and proportion of stroke to diameter.

ARTICLE 2. Indicator Connections.

Each cylinder shall be drilled and tapped by the builder for indicator connections, by means of one-half inch pipe, in the usual manner, and to the satisfaction of the judges. Pet drainage cocks must be on the cylinder. The cross head, or other moving part, must be drilled for the indicator cord attachment.

ARTICLE 3. Clearance.

Each cylinder shall be drilled and plugged at both ends, so as to admit of being completely filled with water and emptied by means of a one-half inch pipe, in order to determine the clearance and the piston displacement of one stroke at each end. These data will be obtained both hot and cold.

ARTICLE 4. Valves.

The steam and exhaust valves will be tested under full steam pressure, ninety (90) pounds per square inch by the gauge, unless some other pressure has been agreed upon for the test.

Article 5. Piston Packing.

The tightness of the piston packing will be determined by removing the back cylinder heads, and subjecting the piston to full boiler pressure on each centre.

Article 6. Fly Wheel.

Each maker is requested to use such diameter of band fly wheel, or of pulley, as shall give a belt speed of 4,000 feet per minute.

Should he require a different belt speed, he will specially note the same in communicating with the Exhibition Committee.

Article 7. Steam Pipes.

Each exhibitor will be required to furnish his own connection with the main steam pipe, the main injection pipe, and the main overflow pipe or tanks.

Article 8. Space.

Each exhibitor will be furnished with space at the regular rates established for the Exhibition, in which space he must build his foundations at his own cost, and subject to the approval of the Superintendent.

Article 9. Specifications.

Each exhibitor will communicate to the Chairman of the Committee of Judges on Steam Engines, such description and drawings of the engine exhibited as will facilitate the labors of that Committee, together with his claims as to the meritorious points for his exhibit.

The Following Points will have Special Consideration.

(1.) Economy of steam.
(2.) Regularity of speed.
(3.) Concentration of power.
(4.) Durability of construction.
(5.) Simplicity of design.
(6.) Excellence of proportions.
(7.) Finish of parts.

Each exhibitor must file the following data:

Diameter of the steam cylinder to the nearest $\frac{1}{100}$ of an inch.
Diameter of the piston rod " " " " "
Diameter of the steam pipe " " " " "
Diameter of the exhaust pipe " " " " "
Diameter of the band, or fly wheel " " " " "
Width of the face, or fly wheel " " " " "
Weight of the fly wheel in pounds.
Area of the steam ports each to the nearest $\frac{1}{100}$ of an inch.
Area of the exhaust ports each " " " " "
Stroke of the engine " " " " "
Indicated horse-power of the engine when working most economically.
Revolutions of the crank per minute.
Weight of the whole engine, exclusive only of the fly wheel.

If a condenser is used and driven by the engine.
Diameter of the air-pumps to the nearest $\frac{1}{100}$ of an inch.
Diameter of the injection pipe " " " " "
Diameter of the overflow pipe " " " " "
Stroke of the air-pump piston " " " " "
If an independent condenser is used, that is not driven by the engine.
Diameter of the injection pipe, to the nearest $\frac{1}{100}$ of an inch.
Diameter of the overflow pipe " " " " "

Drawings of the condenser used, any other data peculiar to it, and a full description of it.

SECTION II.

PREPARATIONS FOR THE TEST.

ARTICLE 10. Steam.

The steam for the tests will be furnished by the exhibition boilers, and will come from boilers specially set apart for the purpose of the tests. It will be charged for at regular rate of three (3) cents per indicated horse-power per hour. Steam, if desired, will be furnished to exhibitors one week before the tests are made.

No charge will be made for the services of attendants or experts, or the use of apparatus, unless in some extraordinary case, when the cost will be fixed by the Superintendent of the Exhibition. No charge against the engine will be made for steam when its power is ordered by the Superintendent for the other purposes of the Exhibition.

ARTICLE 11. Pressure.

The steam pressure used will be subject to the wish of the exhibitor, but shall not exceed ninety (90) pounds per square inch, by the gauge.

A special standard gauge will be used during the test, and subjected to careful tests before and after use.

ARTICLE 12. Safety valve.

The safety valve will be set to blow off at ten (10) pounds above the pressure fixed upon.

ARTICLE 13. Quality of the Steam.

The thermal value, the temperature and the pressure will be taken by means of scale calorimeters, thermometers and standard gauges at the boiler, at the steam chest, and at the exhaust, if the engine is non-condensing.

The thermometers, calorimeters, etc., will be furnished by the Exhibition, but the exhibitor must do such mechanical work, must furnish such piping, tools and materials as are necessary to make the required attachments, at his own cost, and subject to the orders of the Committee of Judges.

ARTICLE 14. Temperature.

The temperatures of injections and of hot well, will be taken with standard thermometers in the case of condensing engines.

ARTICLE 15. Water.

The water used will be taken from the city mains.

The feed water for the boilers will be weighed by means of scales, and a large tank. and will be run into a smaller supplemental tank, from which it will be pumped into the test boilers by means of a feed-pump, actuated by steam from other boilers.

The condensing water used will, in the case of condensing engines, be measured after leaving the hot well, in two carefully gauged tanks, alternately filled and emptied, the temperature also being taken.

The known weight of steam used will be subtracted from the overflow.

The injection water will be weighed in large tanks, and its temperature taken.

The injection water will not be delivered under pressure.

ARTICLE 16. Speed of Engine.

The number of revolutions of the engine will be taken by a continuous counter attached to the crank shaft.

The variations in speed for one minute will be taken at each quarter of an hour by means of an electric chronograph, connected with a standard clock beating seconds.

The variations in speed during one stroke will be taken by an acoustic chronograph at fifteen minutes interval.

Special tests of speed alone, under varying loads, will be made if desired, and close attention will be had to this point in all cases.

ARTICLE 17. Barometric Measurements.

A standard barometer and thermometer will be read at fifteen minutes interval during the trial.

ARTICLE 18. Vacuum.

The vacuum of condensing engines will be read by a gauge, carefully compared before and after the trials.

ARTICLE 19. Testing of Gauges, Indicators, etc.

All of the gauges, indicators and thermometers used, shall be carefully tested before and after the trials, and the party whose engine is tested, shall have the right to be present in person or by agent, at these tests.

ARTICLE 20. Diagrams.

The indicator diagrams will be taken at fifteen (15) minutes intervals, and will be read for:

Initial pressure,
Pressure at cut-off,
Terminal pressure,
Counter pressure at mid-stroke,
Maximum compression pressure,
Mean effective pressure,
Point of cut-off,
Release of steam,
Exhaust closure.

From the diagrams will be computed the indicated steam at the point of cut-off, and at release, as also the actual steam from boilers per horse-power per hour.

ARTICLE 21. Load of the Engine.

The Committee of Judges will test the engine at the load desired by the exhibitor of it, unless circumstances shall render it impossible to meet his wishes.

If the load does not exceed seventy-five (75) indicated horse-power, the net load will be measured by a Transmitting Dynamometer.

ARTICLE 22. Friction Diagrams.

At the close of the regular trial, the engine will have its belt taken off, and be run for one hour for friction diagrams.

ARTICLE 23. Duration of the Trials.

Unless otherwise arranged, the trials will last ten (10) hours.

ARTICLE 24. Economy and Efficiency of the Engine.

No account will be taken of the coal burned, but the economy of the engine will be deduced from the actual steam used and water weighed to the boiler.

The trial will begin with the established pressure.

The level of the water in the boiler, and the pressure of the steam will be kept as nearly constant, as possible, during the whole of the trial.

The whole weight of the water fed to the boiler, subject to proper deductions for waste, and to corrections for variation of level in the boiler, will be multiplied by its thermal value as steam at the steam-chest, and divided by the product of the indicated horse-power of the engine, and the number of hours of the test.

The resulting quotient will be used to divide twenty-five hundred and fifty-seven and sixty-nine one-hundreths (2557·69) British thermal units, giving the efficiency of the engine as compared with the mechanical equivalent of the heat furnished to it, and therefore its efficiency, as a means of converting heat into work.

The net horse-power of the engine will be used for computation similarly to the indicated horse-power, and the result will be taken as the measure of the efficiency of the engine, both as a means of converting heat into work, and as a machine for the transmission of power.

This latter shall be considered the true measure of the efficiency of the engine.

METHODS USED.

TIME OF TEST.

It was the intention that each of these tests should last exactly ten (10) hours. But in the case of the Porter-Allen engine, the engine was stopped to change indicator, and in the case of the Southwark engine, the test lasted eleven (11) hours and two (2) minutes.

STEAM.

The steam used in the engine tests was taken from a boiler which was not in use for any other purpose, and had all valves connecting with other boilers and engines tightly closed. It was not practicable that the steam pipe should be run directly from the boiler used to the engine tested, and in the cases of the Southwark and Porter-Allen engines the steam pipe was very long, and had a number of pockets, in which steam and condensed water lodged. The engines were in all cases run for a considerable time before the tests began, and an endeavor was made to leave the boiler, engine and all their attachments at the end of the test in the same condition as at the beginning.

Before beginning the tests, the level of the water in the boiler was noted, and all water supplied to the boiler after the test began was carefully weighed, so that the amount of water supplied to the engine is known. All water used in calorimetric tests was credited to the engine, and all drips from the main steam pipe were returned to the tanks and used again. The level of the water at the end of the test was brought back to the same point as at the beginning.

DISPLACEMENT AND CLEARANCE.

Before beginning the tests, the engine was put on each dead centre, and the volume on each side of the piston was filled with water, the valve being moved so that it covered the port in each case. The weight of the water required to fill the space and its temperature were taken at the same time, and from this data the displacement of the piston and clearance on each end was calculated.

REVOLUTIONS.

A Crosby revolution counter was attached to the shaft of each engine, and the reading of the counter was taken at regular intervals. After the counter had been adjusted for the engine, it worked

satisfactorily on the Porter-Allen and Buckeye tests, and during the Southwark test, until 4.15 P. M. The number of revolutions on this test after this time are computed from the number of revolutions made by the dynamometer.

BAROMETER.

The readings of the barometer were taken from observations of the U. S. Signal Service in Philadelphia.

PRESSURE AND TEMPERATURE OF THE STEAM.

The pressure of the steam at the engine and at the boiler was taken at regular intervals, and the temperature of the steam was taken at the engine by means of a high grade thermometer set into the branch steam pipe, which led to the calorimeter used, and was very close to the engine.

QUALITY OF THE STEAM.

This was determined by using the Barrus calorimeter, a description of which is given in the Report of the Committee on Steam Boilers.

INDICATOR CARDS.

The indicated horse-power of the engines was taken. The indicator motions used were practically exact. A Crosby and a Tabor indicator were used on each cylinder, and a Crosby was used on the valve chest.

On the Porter-Allen engine test, the indicators were changed when the test was half concluded, and as the cards taken by the two indicators from the same end were as nearly identical as possible, the indicators were not changed during the other tests.

The indicator springs were tested against a Crosby steam gauge, and were found to be practically correct both in ascending and descending.

HORSE-POWER.

The areas of the cards were taken by a Crosby planimeter. The length of the cards were measured to $\frac{1}{100}$ of an inch. The mean effective pressure was determined from this data. The constant for each end of the cylinder was found by dividing the displacement in cubic inches (found by experiment) by twelve times 33,000. This result, multiplied by the mean effective pressure

and by the number of revolutions, gives the horse-power developed in one end of the cylinder. The sum of these results is the total indicated horse-power of the engine.

MEAN INDICATOR CARD.

On each indicator card lines were drawn at right angles to the atmospheric line at the ends of the card, and also at ·05, ·1, ·2—·8, ·9, ·95, the length of the card. The distance from the atmospheric line to both the top and bottom of the card was measured in $\frac{1}{100}$ of an inch and tabulated, by Mr. Green, of the University of Pennsylvania.

A mean of these tabulated results is taken as the mean indicator card from which the amount of water accounted for by the indicator card is calculated. A mean of all the steam chest cards has been taken in the same way, and the mean card has been drawn. It is to be remembered that these mean cards are exactly right only at the points of the stroke already mentioned, and that this card is made of the general shape of cards actually taken.

WATER ACCOUNTED FOR BY INDICATOR CARDS.

In determining the amount of water accounted for on the indicator card, the volume of the cylinder to ·3, ·4, etc., of the stroke, including clearance, has been multiplied by the weight of one cubic foot of steam at the pressure corresponding to that point of the stroke, and from this has been subtracted the volume of the clearance multiplied by the weight of one cubic foot of steam, at the pressure to which the steam has been raised by compression.

This amount being calculated separately for each end of the cylinder, gives the weight of steam accounted for on the card for each stroke. Adding these results together and multiplying by sixty times the mean number of revolutions per minute, gives the total weight of steam accounted for per hour, and dividing by the mean horse-power, gives the water used per horse-power per hour. *It must be remembered that this is on the supposition that the steam in the cylinder was dry and saturated.*

REGULARITY OF SPEED.

These results are given at the end of this report.

The chronograph used consisted of a cylinder about four (4) inches in diameter, revolved by means of clock-work. In front of

this cylinder, carried on a movable table, were two magnets with the armatures arranged in such a way that, when the circuit was closed, a point on the armature rested against the drum, and when the circuit was broken, the point was drawn back from the drum. One of these magnets was actuated by a tuning fork, making about ninety-eight double vibrations per minute, the tuning fork being kept constantly in vibration by a magnet, whose circuit is made and broken by the fork itself.

The other magnet can be actuated in any way, and the records of the two points are side by side on the drum.

During the tests, the circuit of the second magnet was made and broken at each revolution of the engine. The cylinder was covered with smoked paper, and the records made were preserved by dipping them in shellac.

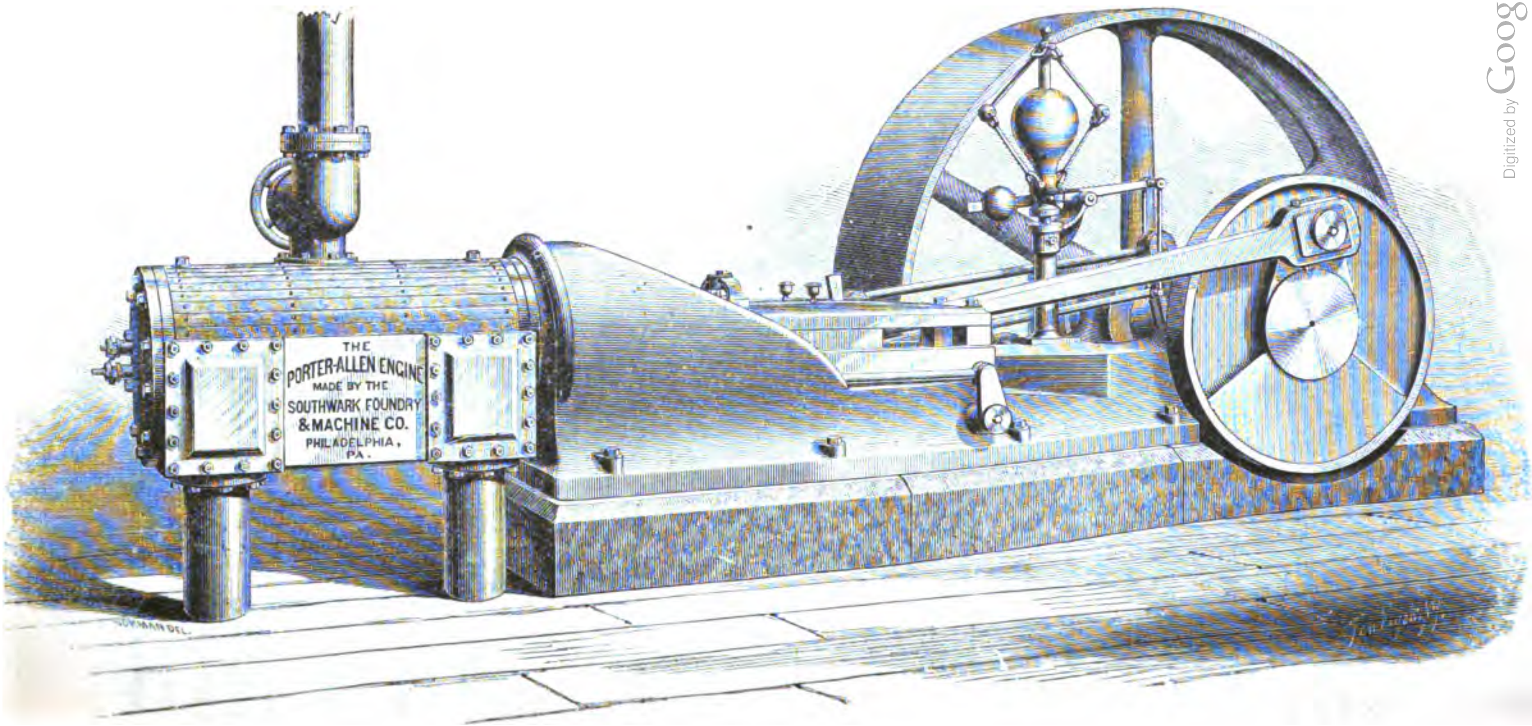
The record then shows the number of vibrations of the tuning fork occurring during successive revolutions of the engine. As it takes considerable time to prepare and adjust the apparatus, it was not possible to make continuous records.

PORTER-ALLEN ENGINE.

Test began,	1·10 P. M., October 23, 1884.
" ended,	11·10 P. M., October 23, 1884.

The engines was stopped 2·9 minutes at 6·15 P. M. to change indicators.

Diameter cylinder,	11½ inches.
Stroke,	20 "
Diameter piston rod,	1¾ "
" steam pipe,	5 "
" exhaust pipe,	5 "
Area steam ports,	6·75 square inches.
" exhaust "	10·94 " "
Diameter fly wheel (belt drum),	66 inches.
Face of " "	15 "
Weight of " "	1,000 pounds.
" " engine complete,	8,500 "
Displacement (measured)—	
Crank end of cylinder,	2018·3 cubic inches.
Head " " "	2070·14 " "
Clearance (measured)—	
Crank end,	127·87 cubic inches.
" "	6·33 % displacem't.
Head end,	136·94 cubic inches.
" "	6·61 % displacem't.
Water used in engine,	27849·07 pounds.



The Porter-Allen Engine.

Total time engine in operation, ...	9 hours 57·1 min.
Mean revolutions per minute, ...	227·51
Maximum " "	230·2
Minimum " "	221·8
Variation from mean speed, ...	+1·18 per cent.
" " " "	—2·51 " "
Mean horse-power (indicated) of engines, . .	69·34
Maximum " " " . .	76·16
Minimum " " " . .	63·16
Mean temperature of steam at engine, . . .	329·33°
Maximum " " " . . .	338·°
Minimum " " " . . .	306·5°
Mean pressure " " . . .	90·5 pounds.
Maximum " " " . . .	101·6 "
Minimum " " " . . .	59·0 "
Mean " " at boiler, . . .	92·8 "
Maximum " " " . . .	104·3 "
Minimum " " " . . .	61·0 "
Mean barometer, ...	30·059 inches.
Mean temperature of air, ...	47·4° Fahr.
Mean power required to run engine with load off,	5·16 H. P.

QUALITY OF THE STEAM.

An attachment was made to the steam pipe just above the valve chest for the Barrus calorimeter, and the following results were obtained from its use:

From 4·40 to 6·40 P. M., October 23d, steam contains 13·36 % moisture
" 6·40 " 8·40 " " " " " 3·23 % "
" 8·40 " 11·10 " " " " " 6·44 % "

The average quality of the steam from this, is that it contained 7·56 per cent. of moisture.

The results of this test are shown graphically in *Fig. 1.*

The scales to which the different parts of the diagram are drawn, are shown on the left hand side of the figure. The base is divided into ten (10) minutes intervals, and the ordinates are laid off correspondingly to the observations made at the regular intervals during the test.

The line marked "Total horse-power" shows the variation in the indicated horse-power during the test.

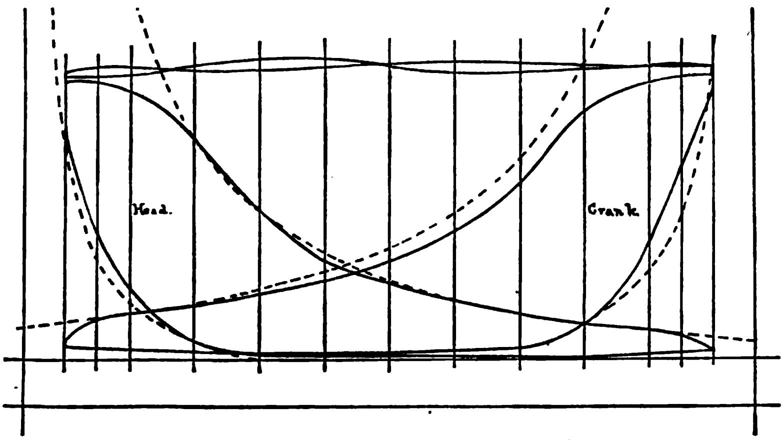
The line marked "Pressure at boiler," shows the variation in steam pressure at the boiler, while the line just below it marked "Pressure at engine," shows the corresponding pressure at the engine.

The line marked "Horse-power follower end" shows the indicated horse-power developed in the end of the cylinder away from the crank, while the line "Horse-power crank end" shows the corresponding power developed in the end of the cylinder nearest the crank.

The sun of the ordinates of the last named lines, should equal the ordinate of the line marked "Total horse-power."

The line marked "Revolutions" shows the variation of the speed of the engine, each ordinate representing the mean number of revolutions for the preceding ten (10) minutes. It will be noticed that the base line does not represent 0 revolutions, but :00. This was done that the variations should be represented on a large scale, and to make the figure as small as possible.

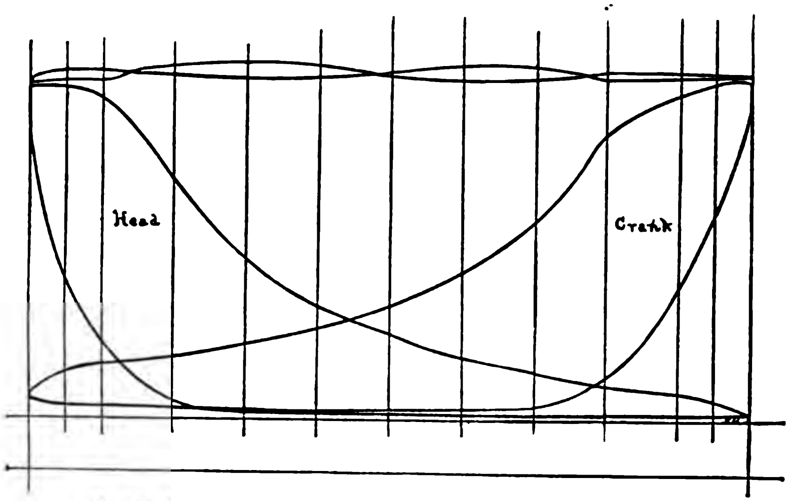
In the diagram, a break is to be noticed in the different lines at 6·15. It would have been more exact to have drawn the lines to the base line instead of breaking them.



Mean Card.—(Porter-Allen Engine.)

Fig. 2.

Fig. 2 shows the mean of all the indicator cards taken during the test, the mean being determined as before described. The clearance line is drawn at each end of the diagram, and the theoretical (hyperbola) expansion and compression lines have been drawn. The scale to which the diagrams are drawn is twenty-five pounds to one inch, and the diagrams in the original are made uniformly, eight (8) inches long.



Porter-Allen, 69·38 Horse-power, 8·45 P. M., Oct. 23, 1884.

FIG. 3.

Fig. 3 is a reproduction of the cards taken at 8·45 P. M., October 23d, showing 69·38 horse-power. This card was chosen, because it comes more nearly to the mean horse-power than any other that was taken.

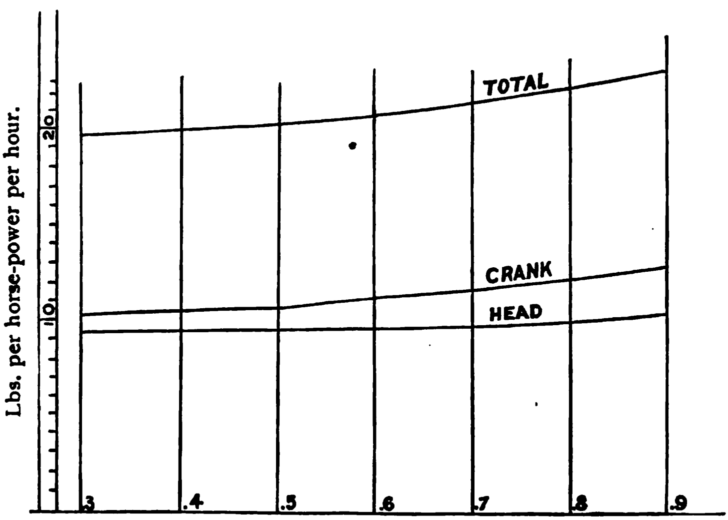
The pressures corresponding to the different parts of the stroke on the mean indicator card, are given in Table I. The first column *A* shows the points of the stroke. The columns headed *B*, show the pressure in the end of the cylinder away from the shaft, while making the stroke towards the shaft and returning, and the column headed *C*, shows the pressures in the opposite end. The column headed *D*, shows the quantity of dry saturated steam used in the cylinder per horse-power per hour from the indicator cards, using the mean number of revolutions and the mean horse-power, and allowing for the amount of steam compressed in the clearance. Re-evaporation after initial condensation is clearly shown by this:

TABLE I.

A. Part of Stroke.	B. Head End Cylinder.		C. Crank End Cylinder.		D. Steam Accounted for in both Ends of Cylinder.
	Advancing.	Returning.	Advancing.	Returning.	
Beginning.	86·28	70·00	87·82	81·63	Clearance, 6·3107 pds.
·05	86·22	38·00	87·72	59·86	
·1	83·88	20·79	85·30	36·42	
·2	69·62	5·47	77·10	11·12	
·3	46·60	2·00	54·72	3·18	19·8733
·4	32·80	1·64	39·70	2·58	20·0799
·5	24·04	1·40	30·42	2·38	20·3880
·6	18·11	1·22	24·40	2·40	20·8786
·7	14·03	1·05	20·18	2·42	21·5601
·8	10·92	9·6	17·06	2·63	22·2940
·9	8·92	1·21	14·84	3·18	23·3827
·95	6·82	1·60	12·74	3·36	
End.	1·88	1·85	6·82	4·32	

The amount of water used by actual weight is 44·307 pounds per horse-power per hour.

No explanation is offered save that already given as to the cause of this discrepancy between the amount of water actually



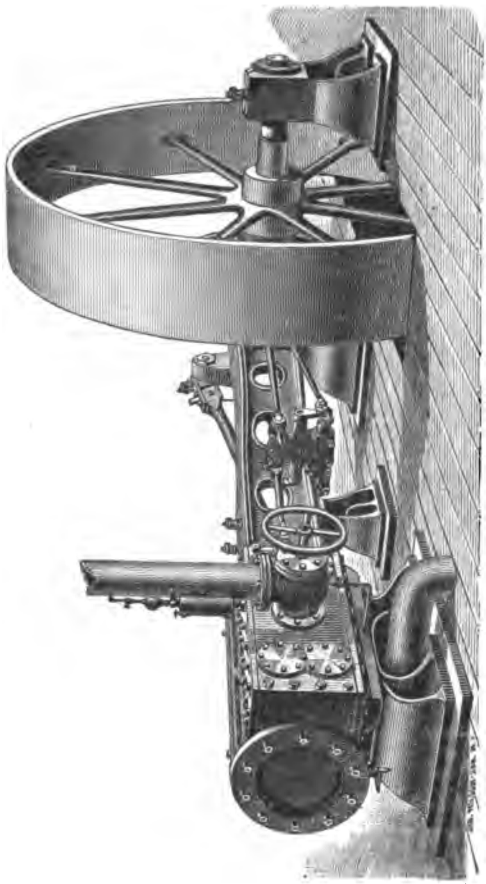
Water in Cylinder. (Porter-Allen.)

FIG. 4.

2*

used in the cylinder and that shown on the indicator cards. The calorimeter test, which cannot be relied upon as accurate, showed an average of 7·56 per cent. of moisture in the steam. At ·9 the stroke where the amount of water shown by the cards is the greatest, the weight of water would be only $\frac{23{\cdot}3827}{{\cdot}9244} = 25{\cdot}295$ pounds, whereas 44·307 pounds actually passed through the cylinder.

Fig. 4 shows the amount of dry saturated steam which should have been present in the cylinder at the different points of each stroke, together with their sum, the upper line being simply a graphic representation of column *D*, of Table I.



The Buckeye Engine.

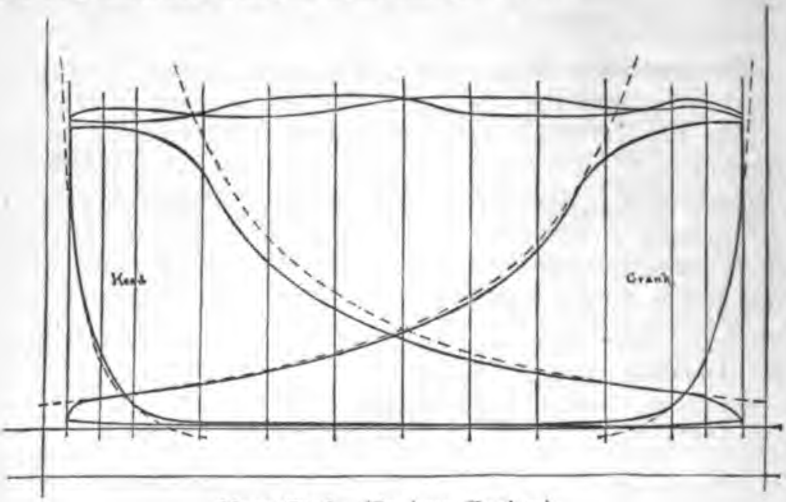
BUCKEYE ENGINE.

Test began,	6 P. M., October 31, 1884.
" ended,	4 A. M., November 1, 1884.
Diameter cylinder,	10 inches.
Stroke,	20 "
Diameter piston rod,	1½ "
" steam pipe,	3½ "
" exhaust "	4 "
Area steam ports,	⅝ x 8¾ inches.
" exhaust "	⅞ x 8¾ "
Diameter fly wheel,	84 inches.
Face of " "	19 "
Weight of fly wheel,	3200 pounds.
Weight of engine complete,	9800 "
Displacement (measured)—	
Crank end,	1464·48 cubic inches.
Head end,	1557·36 " "
Clearance (measured) to face of cut-off—	
Crank end,	47·95 " "
" "	3·27 % displacem't.
Head end,	53·57 inches.
" "	3·44 % displacem't.
Water used in engine,	16803·30 pounds.
Total time engine in operation,	10 hours.
Mean revolutions per minute,	201·11
Maximum " " "	205·6
Minimum, " " "	194·4
Variation from mean speed,	+ 2·23 per cent.
" " " "	— 3·33 " "
Mean indicated horse-power,	54·32
Maximum, " " "	56·27
Minimum, " " "	52·35
Mean temperature of steam at engine,	332·83°
Maximum, " " "	390·°
Minimum, " " "	304·5°
Mean pressure of steam at engine,	98·04 pounds.
Maximum " " "	107·30 "
Minimum " " "	89·80 "
Mean barometer,	30·012
Mean temperature of air,	46°
Mean power required to run the engine with the load off,	5·26 H. P.

QUALITY OF THE STEAM.

The quality of the steam from one observation, lasting from 7·35 to 9·00 P. M., showed the steam to contain 7·6 per cent. of moisture.

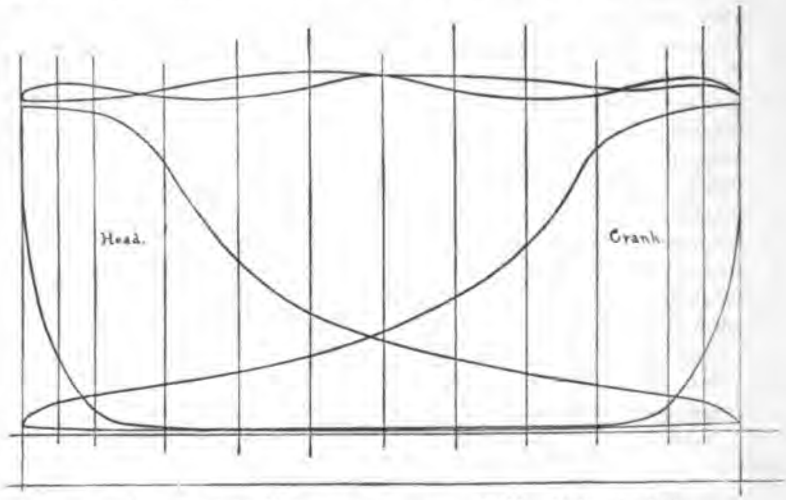
The results of this test are shown graphically in *Fig. 5*. The lines are drawn in the same way as already described for *Fig. 1*, the only difference being a slight change of scale.



Mean Card. (Buckeye Engine.)

Fig. 6.

Fig. 6 shows the mean of all the indicator cards taken during the test, the mean being determined as before described.



Buckeye, 54·34 Horse-power, 11.20 P. M., Oct. 31, 1884.

Fig. 7.

Fig. 7 is a reproduction of the cards taken at 11·20 P. M., October 31, 1884, showing 54·34 horse-power. This card was chosen because it comes more nearly to the mean horse-power than any other that was taken.

The pressures corresponding to the different parts of the stroke, which would give the mean indicator card, are given in Table II.

The first column *A* shows the points of the stroke, *B* is the pressure in the end of the cylinder away from the shaft, while the piston is making the stroke towards the shaft and returning. *C* is the pressure in the opposite end. *D* is the quantity of dry saturated steam in the cylinder per horse-power per hour from the indicator card, using the mean number of revolutions and the mean horse-power, and allowing for the amount of steam compressed in the clearance.

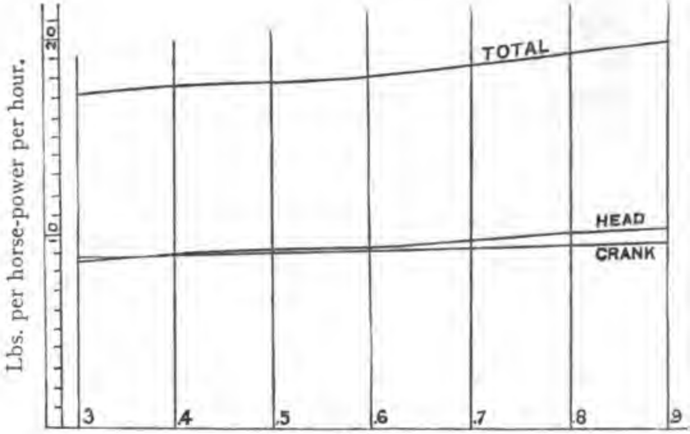
TABLE II.

A. Part of Stroke.	*B.* Head End Cylinder.		*C.* Crank End Cylinder.		*D.* Steam Accounted for in Both Ends of Cylinder.
	Advancing.	Returning.	Advancing.	Returning.	
Beginning	90·58	78·72	90·95	76·52	
·05	90·49	21·82	90·95	20·34	
·1	89·46	6·94	89·86	6·40	
·2	76·76	1·79	80·42	1·39	
·3	49·25	1·62	52·94	1·14	17·310
·4	35·04	1·50	37·40	1·08	17·743
·5	26·32	1·38	28·18	·94	18·270
·6	20·40	1·00	21·64	·90	18·713
·7	16·29	·56	16·98	·92	19·226
·8	13·12	·42	13·40	1·04	19·689
·9	10·39	·52	10·65	1·22	20·062
·95	8·28	·68	9·26	1·49	
End.	1·95	1·95	3·76	2·40	

Amount of water used by actual weight $= \frac{16803 \cdot 3}{10 \times 54 \cdot 32} = 30 \cdot 93$ pounds.

This engine was immediately adjacent to the boiler.

As the calorimeter test shows but 7·6 per cent. of moisture, it is evident that the steam shown on the card and that actually passing through the cylinder, vary greatly.



Steam in Cylinder. (Buckeye Engine.)

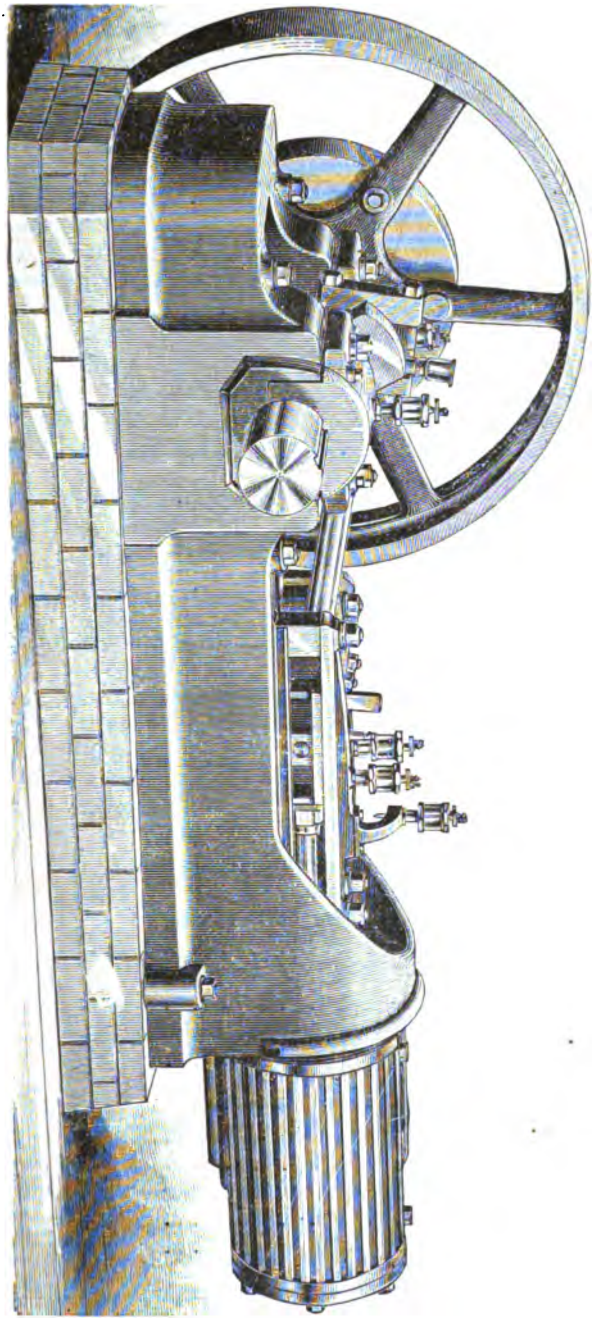
FIG. 8.

Fig. 8 shows the relative weights of dry saturated steam that should be present (theoretically) in the cylinder at different points of the stroke, together with the amount per horse-power per hour, as shown in Table II.

The power given off by this engine was transmitted directly to a Van Depoele dynamo mounted on a Brackett dynamometer cradle, and readings were taken from this dynamometer while the indicator cards were being taken. As the dynamometer was afterwards shown to be inaccurate, the results are here omitted. It is to be regretted that circumstances did not allow of a special test to determine the net horse-power delivered.

SOUTHWARK ENGINE.

Test began,	1 P.M., November 8, 1884.
" ended,	12·02 A. M., " 9, 1884.
Diameter cylinder,	9 inches.
Stroke,	10 "
Diameter piston rod,	1½ "
" steam pipe,	3 "
" exhaust "	3½ "
Area steam port,	5·7 square inches.
" exhaust "	5·7 " "
Diameter fly wheel (belt drum),	40 inches.
Face of "	8½ "
Weight of "	400 pounds.



The Southwark Engine.

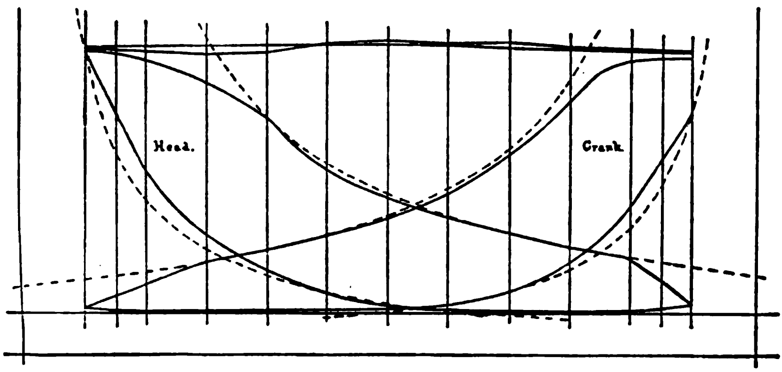
Weight of engine, complete, ...	2,600 pounds.
Displacement (measured)—	
Crank end, ...	606·03 cubic inches.
Head end, ...	633·31 " "
Clearance, (measured)—	
Crank end, ...	66·1 " "
" "	10·91 % displacem't.
Head end, ...	70·42 cubic inches.
" "	11·12 % displacem't.
Water used in engine, ...	14792·07 pounds.
Total time engine in operation, ...	11 hours, 2 minutes.
Mean revolutions per minute, ...	305·06
Maximum " "	309·87
Minimum " "	301·
Variation from mean speed, ...	+1·57 per cent.
" " " "	−1·33 " "
Mean horse-power of engine, ...	29·11
Maximum " " "	46·82
Minimum " " "	14·97
Mean temperature of steam at engine, ...	329·16°
Maximum " " "	335·°
Minimum " " "	315·°
Mean pressure " "	87·58 pounds.
Maximum " " "	96·0 "
Minimum " " "	68·5 "
Mean " " at boiler, ...	92·97 "
Maximum " " "	101·3 "
Minimum " " "	73·0 "
Mean barometer, ...	30·256
Mean thermometer, ...	
Mean horse-power delivered, as shown by Tatham's dynamometer, ...	23·44
Maximum horse-power delivered, as shown by Tatham's dynamometer, ...	43·15
Minimum horse-power delivered, as shown by Tatham's dynamometer, ...	9·13
Mean horse-power required to run engine with belt off, ...	4·68

QUALITY OF THE STEAM.

From 3·10 to 4·10 P. M., November 8th, steam contained, ...	6·7 % moisture.
From 9·50 to 10·55 P. M., November 8th, steam contained, ...	9·15 % "
Mean quality of steam, containing, ...	7·92 % "

The results of this test are shown graphically in *Fig. 9*. In

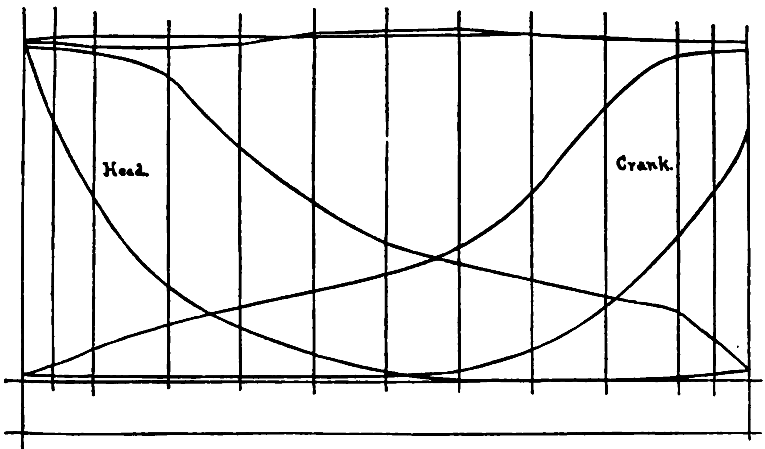
addition to the lines which have already been described, there is one marked "Horse-power from dynamometer," which represents the horse-power delivered by the engine to the Tatham Dynamometer.



Mean Card. (Southwark Engine.)

FIG. 10.

Fig. 10 shows the mean of all the indicator cards taken during the test, the mean being determined as before described.



Southwark, 29·21 Horse-power, Nov. 8, 7·15 P. M., 1884.

FIG. 11.

Fig. 11 is a reproduction of the cards taken at 7·15 P. M., November 8, 1884, showing 29·21 horse-power. This card was chosen, because it comes more nearly to the mean horse-power than any other that was taken during the test.

The pressures corresponding to the different parts of the stroke, which would give the mean indicator card, are given in Table III.

The first column *A* shows the points of the stroke. *B* is the pressure in the end of the cylinder away from the shaft, while the piston is making the stroke towards the shaft and returning. *C* is the pressure in the opposite end. *D* is the quantity of dry saturated steam in the cylinder per horse-power per hour from the indicator card, using the mean number of revolutions and the mean horse-power, and allowing for the amount of steam compressed in the clearance.

TABLE III.

A. Part of Stroke.	*B.* Head End Cylinder.		*C.* Crank End Cylinder.		*D.* Steam Accounted for in both Ends of Cylinder.
	Advancing.	Returning.	Advancing.	Returning.	
Beginning.	86·80	87·56	84·99	67·14	
·05	86·08	66·21	84·99	50·55	
·1	83·90	47·38	84·32	35·02	
·2	76·69	25·56	71·05	16·92	
·3	62·58	14·25	52·62	7·00	20·781
·4	47·51	6·36	39·40	2·44	21·201
·5	37·97	2·17	31·84	1·36	22·155
·6	32·06	0·44	25·60	1·08	23·107
·7	26·75	0·07	20·90	·69	23·676
·8	22·38	0·11	17·08	·42	24·045
·9	18·24	0·49	9·74	·58	
·95	11·20	1·46	5·27	1·16	
End.	3·47	2·77	1·98	1·80	

The amount of water used by actual weight per horse-power per hour

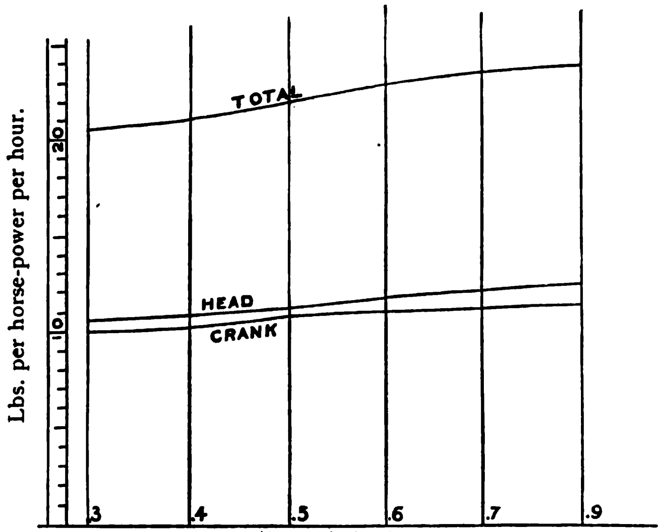
$$= \frac{14792{\cdot}07}{11\frac{1}{30} \times 29{\cdot}11} = 46{\cdot}05 \text{ pounds.}$$

The load on this engine consisted of the Tatham dynamometer and a friction brake, and the variation in this latter caused the great variation in the horse-power lines on *Fig. 9*.

Fig. 12 shows the relative weights of dry saturated steam that should be present (theoretically) in the cylinder at different points of the stroke, together with the amount for horse-power per hour, as shown in Table III.

REGULARITY OF SPEED.

A good idea of the regularity of speed can be obtained from *Figs. 1, 5* and *6*, which show the average number of revolutions made by the engine for each ten or fifteen minutes, as the case may be. This only, however, gives the mean speed for successive inter-



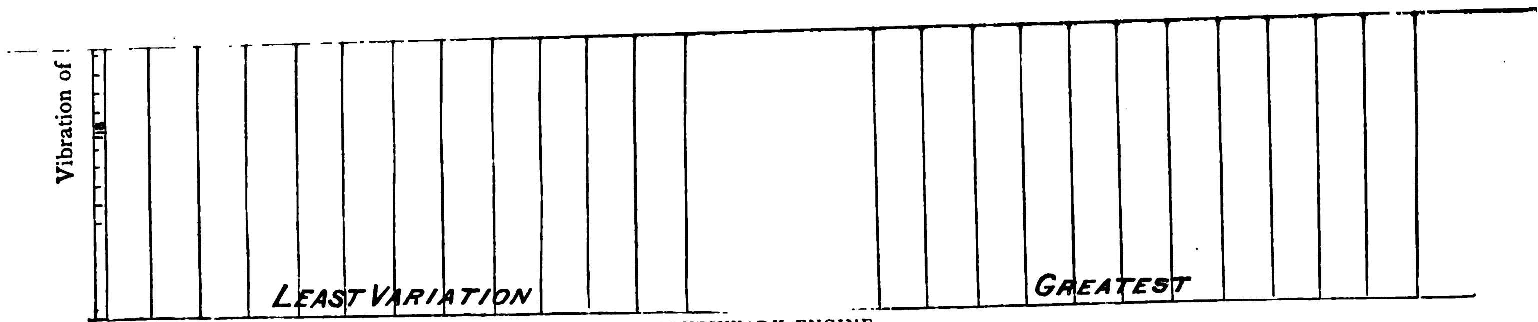
Parts of Stroke.
Steam in Cylinder. (Southwark Engine.)

FIG. 12.

vals of time, and does not show the time required to make successive revolutions, which would be a more accurate test of the regularity. *Fig. 13* is a specimen of the record taken to determine the time of successive revolutions. *Fig. 14* shows the results of these experiments graphically, the horizontal distances being the successive revolutions, and the vertical distances being the time it takes to make each revolution, the unit of time being that of the double vibration of a tuning fork making about ninety-eight double vibrations per seconds.

During both the Porter-Allen and the Southwark tests a number of diagrams were taken, but only the results of those showing the last and greatest variation in speed are shown in *Fig. 14*. The following table, No. IV., gives the time ot making successive revolutions in beats of the tuning fork, and they can be reduced to revolutions per minute by dividing with 5,880 = (98 x 60) :

Fig. 13



SOUTHWARK ENGINE.

TABLE IV.

Porter-Allen.		Southwark.	
Minimum Variation.	Maximum Variation.	Minimum Variation.	Maximum Variation.
25·92	26·51	18·75	19·3
25·96	24·72	19·00	19·1
26·13	25·56	19·0	19·2
26·00	25·33	19·0	19·2
26·00	25·30	19·0	18·8
26·07	25·60	19·0	18·7
26·00	25·43	18·9	18·7
26·01	25·55	18·9	18·8
26·00	25·41	19·0	19·0
26·10	25·43	18·9	19·0
26·13	25·57	19·0	19·0
25·95	25·71	19·0	19·0

The nearly continuous line of *Fig. 13* is from the armature, making record of the revolutions of the engine, and as the circuit was broken at only one point in the revolutions, the tracing point would make a continuous line, except during one small interval. The dots right under this line are made by the other armature. connected with the tuning fork. *Fig. 15* will show the manner of connecting and using the apparatus. All the apparatus shown in the figure, excepting the piece marked *T* and the cells *V*, *W* and *X*, is on one base and works as follows: The tuning fork *Z* is kept in vibration by means of the single Leclanché cell *X*, which is connected to the binding posts *A* and *B*. *A* is connected directly to the tuning fork *E*, as the whole apparatus rests on an iron base, and *E* and *A* are not insulated. The current passes from *X* to *B*, then around the magnet *G*, then to the insulated contact piece *F*, through the contact piece to the fork *Z*, from *E* to *A*, and back to the cell *X*.

The vibration of the fork makes and breaks contact at *F*, magnetizing and demagnetizing *G* and keeping the fork vibrating with about a constant amplitude of vibration.

The drum *P* is the drum on which the records are made. *N* and *O* are two small magnets with their armature balanced horizontally in such a way that while the circuit is closed through them, the points *a*, *a*, rest against the drum, and when the circuit

is open a light spring draws the points clear of the drum. The magnet O is the one represented as recording the vibrations of the fork. The binding posts I and K are connected to the coil of the magnet.

The current from the cell W passes from W to the uninsulated post C. From C through the frame to the fork Z, through the

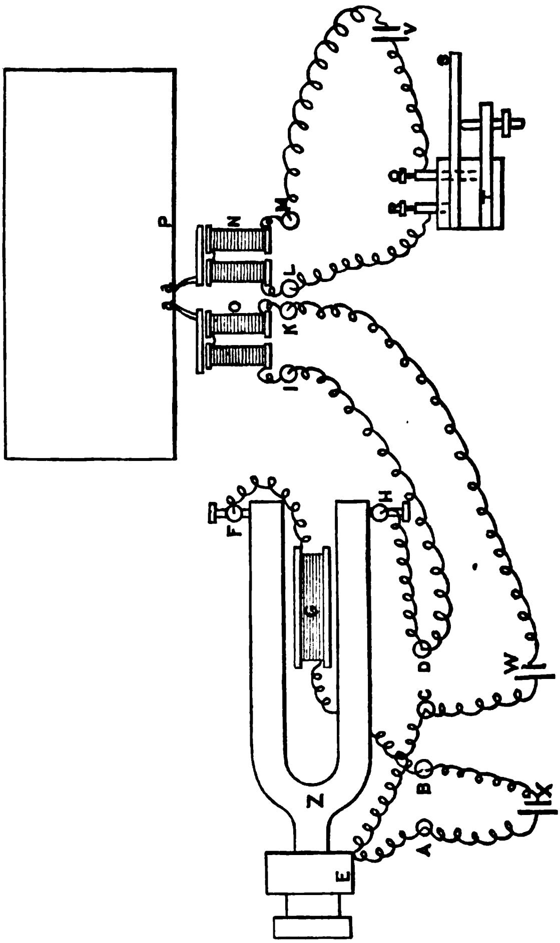


FIG. 15.

contact piece to the insulated post H, which is connected to the binding post D, also insulated. D is connected to I and the current, after passing through the coil of the magnet, passes through K back to the cell W. As the current is broken at H the point a is raised from the drum P, and as soon as the circuit is closed, the point a again rests on the drum P.

The record of the other magnet is made as follows: *T* is the break circuit piece. It consists of two brass pieces, *S* and *T*, insulated from each other and connected to the binding posts *R* and *Q*. *U* is a contact screw. *S* is put in such a position that a projection on the engine strikes *S* once a revolution, breaking contact with *U*. Connections are made, as shown, to the magnet *N*, and when the circuit is closed, the current flows through *M*, *N*, *L*, *R*, *S*, *U*, *T*, *Q*, and back to the cell *V*, in the order named.

In addition to the records made by this apparatus the following experiment was made on the Porter-Allen engine. The projecting end of the shaft was covered with blackened paper, and while the engine was in operation a point attached to one arm of a tuning fork was brought against the paper for a single revolution. This was repeated a number of times.

A straight line was drawn on the paper cutting the marks made by the fork, and the distance between successive vibrations has been plotted. The results are shown in *Fig. 16*. The ordinates are the actual distances between vibrations in inches. The abcissæ are equal intervals of time during one revolution. The points marked *D* represent the dead points. An examination will show that the changes in speed do not take place at any particular place in the stroke, and none of the diagrams taken show any more marked variation than those in the figure.

The thanks of this Committee are due to the following parties:

The Crosby Steam Gauge and Valve Company, Boston, Mass., for planimeters, gauges, indicators and test pumps, all of which proved of excellent workmanship.

The American Steam Gauge Company, Boston, Mass., for Tabor indicators, which worked well. A Mosscrop speed indicator, loaned by the same firm, was not used.

Riehlé Brothers, Philadelphia, Pa., for use of scales.

M. B. Edson, for a very accurate recording and alarm gauge.

The students of the Department of Dynamical Engineering, University of Pennsylvania, already mentioned in "Report on Boilers," for services as observers and computers.

As none of the exhibitors made application for a competitive test as prescribed under the code, all tests are quantitative. The uncertainty of the Committee as to the correctness of the calorimetric observations, and the fact that the engines were placed at

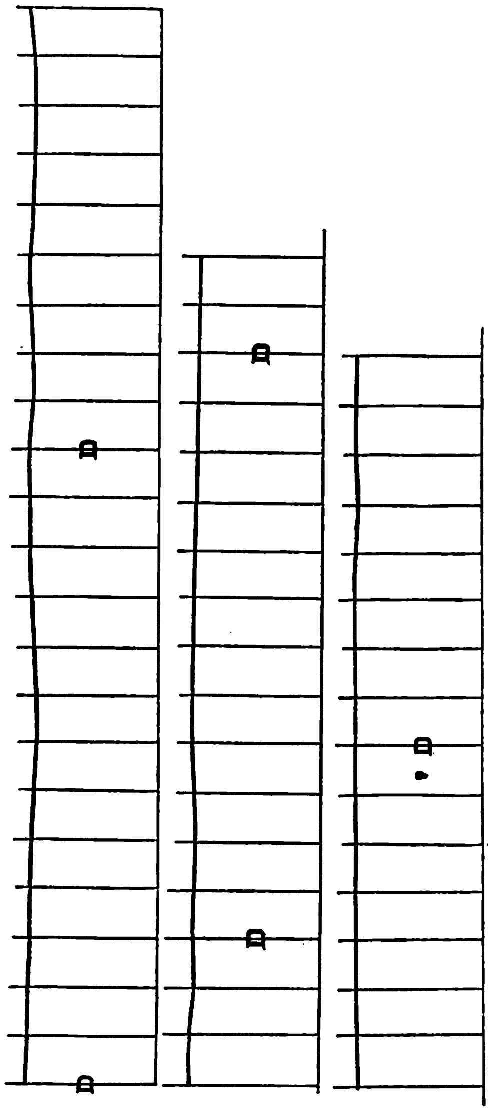


Fig. 16.

very different distances from the boiler feeding them, cause the Committee to submit their results without an expression of opinion.

W. D. Marks, *Chairman.*
Chas. E. Ronaldson.
W. B. LeVan.
Committee Present.
H. W. Spangler, *Secretary.*

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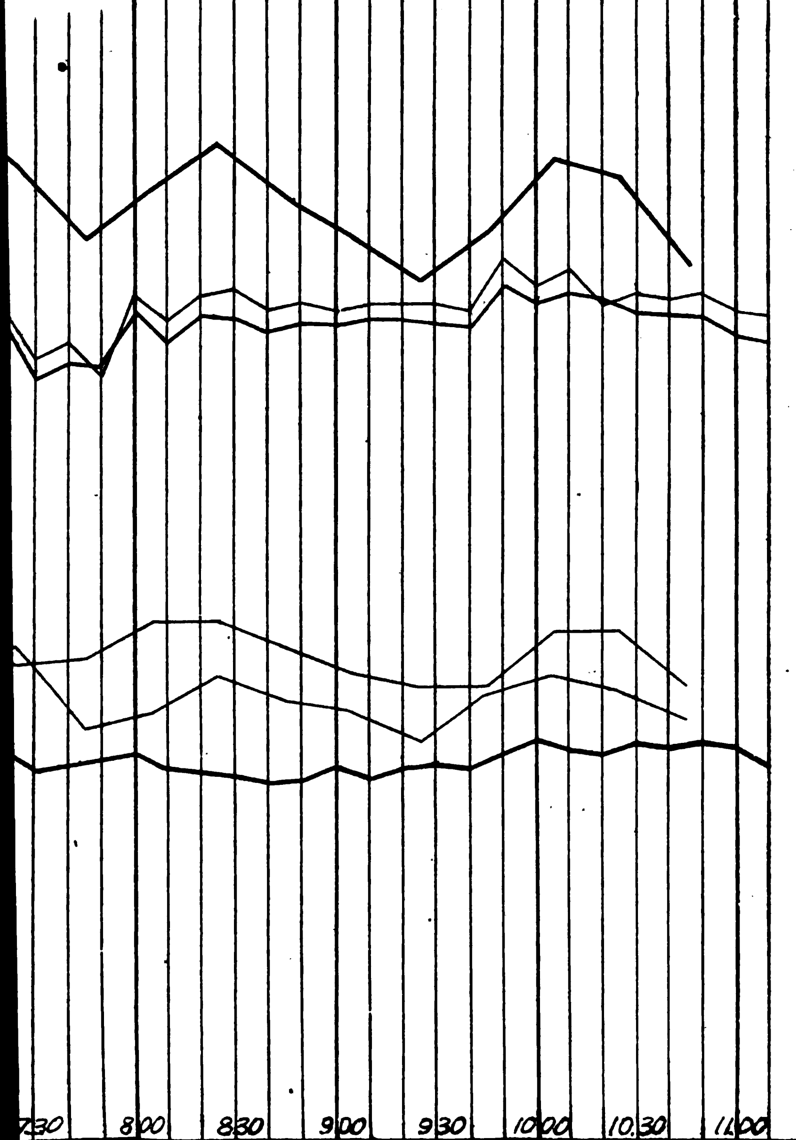

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XII.

(SECTION I, CLASS VI. OF THE CATALOGUE.)

GAS ENGINES.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, OCTOBER, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1885.

EDITING COMMITTEE.

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1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XII.—GAS ENGINES AND OTHER PRIME MOTORS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XII. on "Gas Engines and other Prime Motors." Respectfully, M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, June, 1885.

Professor M. B. SNYDER, *Chairman Board of Examiners, International Electrical Exhibition:*

SIR:—The Examiners in Section XII. (on "Gas Engines and other Prime Motors,") respectfully present the following report.

J. BURKITT WEBB,

Chairman of Section XII.

ITHACA, N. Y., June, 1885.

GAS ENGINES AND OTHER PRIME MOTORS.

Upon the organization of Section XII., it was found that their work would probably be limited to the examination of gas engines; it was therefore decided to adopt a code for these only, and to prepare for tests of a scientific character, which might solve doubtful points in the operation of these engines, and a committee was appointed to draft such a code.

At the next meeting of the Section, the following code was reported by the committee and was adopted by the Section, and a further committee was charged with the duty of making definite arrangements with the exhibitors of gas engines, whereby they should submit certain engines to be tested by the Section in accordance with the code and any necessary additional arrangements.

CODE OF TESTS OF GAS ENGINES.

[Approved, September 8, 1884, by Section XII. of the Board of Examiners of the International Electrical Exhibition of the FRANKLIN INSTITUTE, Philadelphia, Pa.]

The aim of the experiments will be two-fold:

I. A PRACTICAL TEST to determine the efficiency of the engines exhibited under conditions regarded as the most favorable by their makers, with a view solely to the acquirement of practical information regarding the economy and reliability of the several engines.

Such determination will consist of:

(*a*.) A ten-hour test under maximum load.

(*b*.) A ten-hour test under minimum load.

(*c*.) A ten-hour test under average load, the engine being stopped at the end of each hour and the time lost in re-starting noted.

The data collected will consist of:

(1.) Indicator cards.
(2.) Prony brake readings.
(3.) Velocity and regularity of rotation.
(4.) Total number of revolutions.
(5.) Total number of explosions.
(6.) Temperatures of entering gas and air.
(7.) Temperature of exhaust gas.
(8.) Temperature of entering water.
(9.) Temperature of escaping water.
(10.) Pressures of entering gas and air.
(11.) Analysis of entering gas.
(12.) Analysis of escaping gases.

II. A Scientific Test to determine certain details of the action of the gas inside the cylinder, valuable and desirable in view of the imperfect state of our knowlage of gas engines from a theoretical standpoint.

For this purpose some one engine will be selected and the attempt made to obtain the following data, in addition to those secured in the practical test.

(1.) Temperature of gases after explosion; by means of the electrical resistance of fine platinum wire placed in the cylinder.

(2.) Effect of varying amounts of compression.

(3.) Effect of varying mixtures.

(4.) Effect of compressing the gas and using it through a reduction-of-pressure regulator.

(5.) Effect of heating the entering gas.

(6.) Inflammability of the charge by an electric spark at different points of the cylinder.

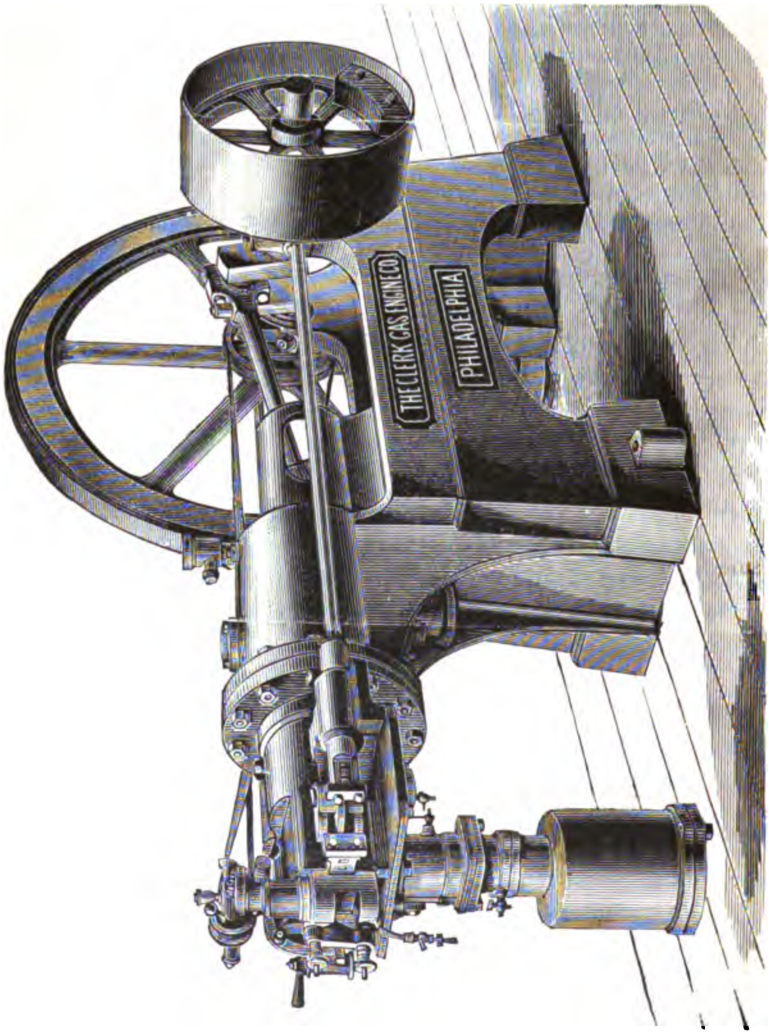
(7.) Effects of variations of speed and changes of valve settings, etc.

(8.) Dissociation experiments.

After conference with the exhibitors, the committee reported that they were unwilling to submit their gas engines to the tests proposed by the committee; no such tests were therefore made, and the report is confined to simple notices of the engines exhibited.

The Clerk Gas Engine Company, of Philadelphia, exhibit two of their engines of, respectively, eight and ten horse-power, which drive Ball unipolar dynamos, six arc lights being maintained by the smaller engine and eighty incandescent lights by the larger. This engine is constructed with two cylinders—a working cylinder, in which a mixture of gas and air is exploded at each revolution, and a "displacer" cylinder, by which the remnants of the waste gases are blown out of the working cylinder and a fresh charge of the explosive mixture furnished.

The pressure in the "displacer" cylinder is never over five pounds, the volume is, however, greater than that of the working cylinder; its piston is driven by a crank a quarter revolution in advance of the working crank. During the first half of its stroke, it sucks in a combustible mixture of gas and air, while during the remainder of the stroke only air is admitted; the first half of the return stroke, therefore, must force this half cylinder full of air into and through the working cylinder, and the combustible mixture will be forced into it during the last half of the stroke. Owing to the relation of the cranks this first half of the return stroke corresponds to the last eight of the outward and the first eight of the return stroke of the working cylinder; the air, therefore, washes

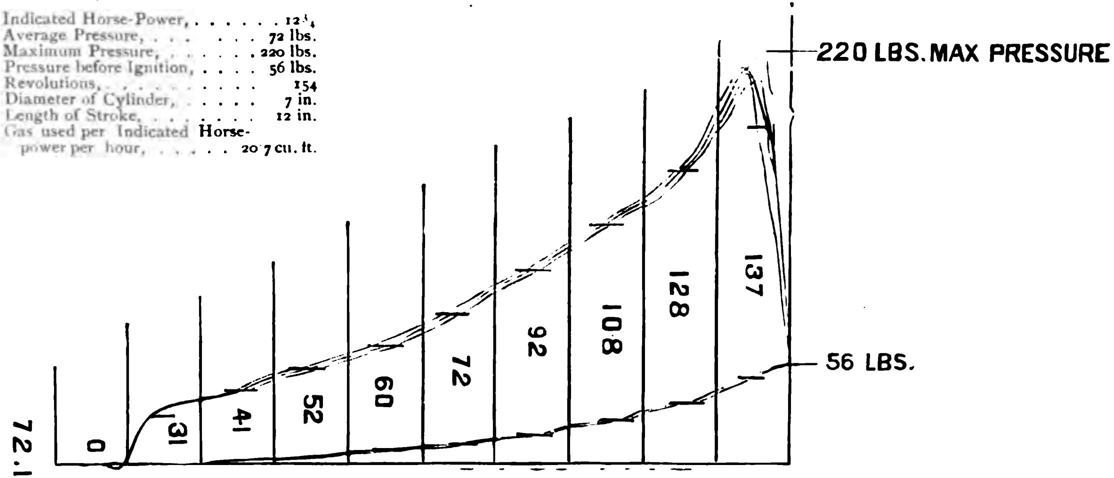


CLERK GAS ENGINE.

out and cools the latter while the piston is at the outward end of it. The exhaust of the working cylinder is by means of annular ports uncovered by the piston at the outward end of its stroke, and in order that the air may escape and the combustible mixture be fairly in the cylinder before these ports are closed, the volume of the "displacer" cylinder is made larger than that of the working cylinder plus its "clearance." The return stroke of the working piston compresses the mixture to say fifty pounds pressure per square inch, and it is then exploded, the pressure rising to from 200 pounds to 250 pounds. The charges are fired by means of a Bunsen burner and "ignition slide." These engines have also an attachment, by means of which compressed gas is used for starting them. This consists principally of a reservoir, into which the "displacer" cylinder can be made to compress the combustible mixture to, say, seventy pounds pressure. This is effected by a valve, which prevents the mixture from entering the working cylinder; the compression is, therefore, accomplished by the stored energy of the fly wheel and must be done a little at a time so as not to stop the engine. Following is a cut and indicator diagram of these engines, with dimensions and weights of various sizes:

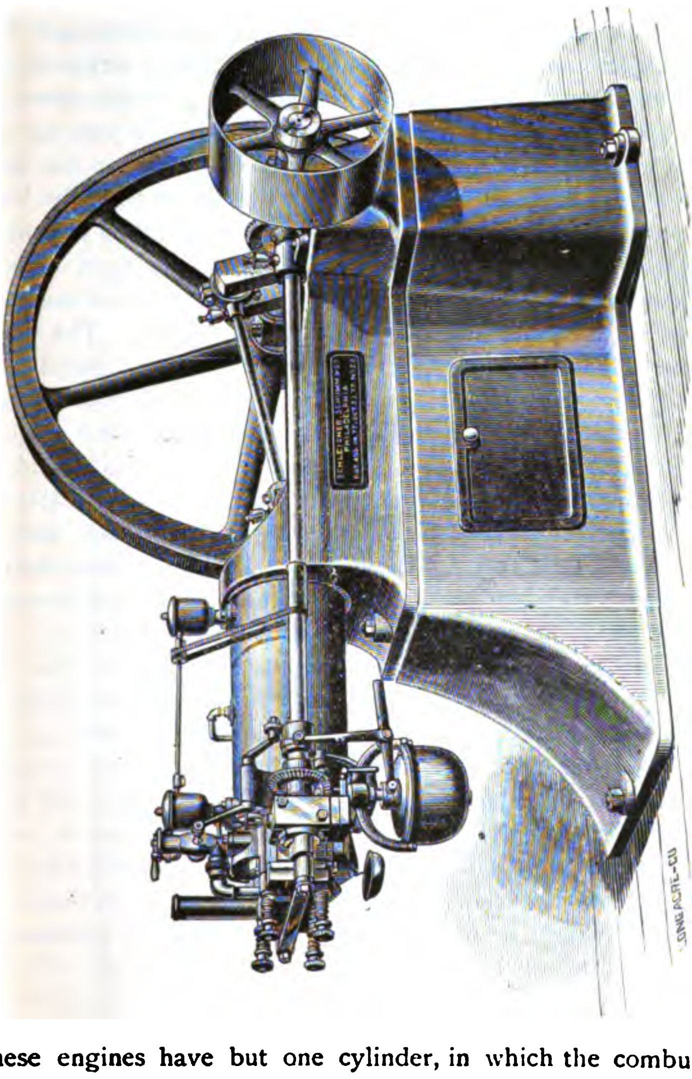
DIAGRAM (furnished by the Company,) OF A 10 HORSE-POWER CLERK GAS ENGINE.

Indicated Horse-Power, ... $12\frac{3}{4}$
Average Pressure, ... 72 lbs.
Maximum Pressure, ... 220 lbs.
Pressure before Ignition, ... 56 lbs.
Revolutions, ... 154
Diameter of Cylinder, ... 7 in.
Length of Stroke, ... 12 in.
Gas used per Indicated Horse-power per hour, ... 20·7 cu. ft.



No. of Engine.	Indicated Horse-Power.	Motor Cylinder. Diameter.	Motor Cylinder. Stroke.	Driving Pulley. Diameter	Driving Pulley. Face.	Revolutions.	Floor Space.	Height.	Weight of Engine Complete.
1	4 to 5	5 in.	8 in.	16 in.	6½ in.	210	6 ft x 3 ft.	2 ft. 8 in.	2,100 lbs.
2	8 " 9	6 in.	10 in.	18 in.	8 in.	180	8 ft x 3 ft. 5 in.	4 ft. 9 in.	2,700 lbs.
3	10 " 14	7 in.	12 in.	24 in.	10 in.	150	9 ft. x 3 ft. 6 in.	5 ft. 6 in.	3,800 lbs.
4	15 " 17	8 in.	16 in.	28 in.	12 in.	140	12 ft. x 3 ft. 9 in.	6 ft. 4 in.	5,800 lbs.
5	25 " 27	9 in.	20 in.	32 in.	14½ in.	130	13 ft x 5 ft.	6 ft. 4 in.	7,800 lbs.

Schleicher, Schumm & Co., of Philadelphia, exhibit three of their standard "Otto" Silent Gas Engines, respectively of four, seven and fifteen horse-power, the two former driving, the first a 25-light Edison dynamo, and the second a 40-light Bernstein.



"OTTO" GAS ENGINE.

These engines have but one cylinder, in which the combustible mixture is compressed and exploded during alternate revolutions. It is claimed that this engine possesses the least number of work-

ing parts, and the greatest simplicity of mechanism ever yet attained in a gas engine, or even in many steam engines.

Messrs. Queen & Co., of Philadelphia, exhibit a small steam engine, using petroleum as a fuel and suited for use in the lecture room.

The boiler of this engine consists of a cast-iron water-back, from which project about fifty horizontal cast-iron tubes, 9 inches long by 1¼ inches diameter, the whole surrounded by a double sheet-iron jacket open underneath and terminating above in a pipe for connection with a chimney. Among these tubes is blown the flame from a petroleum atomizer, operated by live steam from the boiler and controlled by a pressure diaphragm, which shuts off the supply of steam when the boiler pressure rises above the right amount. This arrangement, entirely automatic, maintains the steam at a fixed pressure whether the engine be running or not. The supply of water is also regulated automatically by a float. Besides the arrangements described, there are also the usual steam gauge, safety valve and water glass. The engine is enclosed in a cast-iron case into which it exhausts, it is supplied with a self-oiler and the case has a pan bottom, in which the oil and condensed water collect, and from which they are splashed by the crank, etc., over the whole engine, thus keeping it well oiled. The engine is an inverted one, having two single acting cylinders end to end above the crank, with steam chest and simple cock-valve between them. The pistons have no packing and are united by a piston rod, also without packing, running through the steam chest, the connecting rod being hinged to the lower piston. The simple cock valve is operated by a movable eccentric, whose position is controlled by centrifugal force acting in opposition to a spring, and the supply of steam is thus controlled; the engine has therefore an automatic cut-off. The exhaust is by means of annular ports in the walls of the cylinders, which are uncovered by the pistons at the ends of the stroke.

At the request of Messrs. Queen & Co., and in presence of their representative, a short test was undertaken October 18, 1884, to ascertain the working qualities of the engine, and with the following results:

To start the engine it was run backwards a few times by hand, and air was thus compressed into the boiler, sufficient to run the atomizer until there was a pressure of steam sufficient to run it;

in a few minutes the pressure stood at 105 pounds. The coal oil and water were then weighed and the temperature taken, the brake adjusted, and the test commenced. The test was continued for over an hour, the engine running at about 500 revolutions per minute, with the brake adjusted to absorb the maximum amount of work, and it was found difficult to maintain the steam at more than seventy-five pounds pressure with the full load on. The general result of the test was that the engine would develop four-tenths horse-power with a consumption of five pounds fourteen ounces of oil, and twenty-six pounds of water at 70° Fahrenheit, per hour.

Respectfully submitted,

J. BURKITT WEBB, *Chairman*,
S. LLOYD WIEGAND,
W. BARNET LEVAN.
LUTHER L. CHENEY.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTIONS XIV-XVI.

(SECTION 1, CLASSES II AND III, OF THE CATALOGUE.)

BATTERIES.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, APRIL, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE
1885.

EDITING COMMITTEE.

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WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XIV.—BATTERIES.

To the Board of Managers of the Franklin Institute:

GENTLEMEN:—I have the honor of herewith transmitting to you the report of Sections XIV, XV and XVI, of the Board of Examiners. The material for the latter two Sections was but meagrely represented at the exhibition, and they were therefore merged with Section XIV.

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, *February* 16, 1882.

Prof. M. B. SNYDER,

Chairman of Board of Examiners,

International Electrical Exhibition:

I herewith submit the report of the Section on Batteries. The factors of the primary batteries were measured by Prof. Dolbear, who was aided in the readings by Dr. William Drysdale and Prof. Greene. The measurements of secondary batteries were made by Profs. Van Dyck and Greene, aided in the readings by Drs. Drysdale and James, Prof. Sadtler and Mr. J. Morgan Eldridge. Mr. P. H. Russell, not a member of the Board of Examiners, was of valuable service in the tests of both primary and secondary batteries, and the examiners hereby express their thanks.

Respectfully,

F. C. VAN DYCK,

President of Section XIV.

WM. H. GREENE.

Secretary of Section XIV.

REPORT ON BATTERIES.—SECTION XIV.

There were thirteen varieties of batteries offered for examination. Most of these were represented by as many as two cells and one by five cells.

The committee was not asked to examine any cell to determine its fitness to do a certain kind of work. It therefore considered each kind of a cell as a device for furnishing a difference of electric-potential in an electric-circuit, and for maintaining a current of electricity for such an interval of time as was at the disposal of the committee for its observation.

The uses to which a galvanic battery may be put are so various and the capabilities of different cells are so different that the committee felt some embarrassment at the outset in settling upon a plan of observations that could be completed in the limited time, which would be given to it, and at the same time not do injustice to a class of galvanic cells capable of excellent work in a way different from that of another class.

Roughly, batteries may be classed in two divisions, namely: I, closed circuit batteries or those adapted to be kept in constant working circuit, such as the various forms of Daniel's cells; and II, open circuit cells, or those adapted to intermittent service, and which require more or less time after use to recover their ability to do further work at the same rate as at first, as is the case with the various forms of ammonium chloride cells; but in the majority of cases when a battery is wanted it is wanted for immediate current strength, and a knowledge of the rate of decrease in strength, or of the time a given cell may be depended upon to furnish a current of given strength will enable one to judge fairly as to the availability of a given cell for a known purpose.

Now the current which a given cell will yield at any instant depends upon the electro-motive force of the cell at that instant, and the total resistance in its working circuit. The total resistance in the circuit, includes, of course, the internal resistance of the cell itself, and this factor is a very variable one, and most discordant results are obtained when it is measured under different circumstances; such for instance as with small and with great external resistance. It happens also that the electro-motive force of a cell as measured by the difference of potential of its terminals, and the electro-motive force available in a closed circuit with the cell may be very different quantities.

The one depending upon the kind of materials used in the cell and their disposition, the other varying with the resistance external to the cell.

Hence it becomes necessary to ascertain the electro-motive force of the cell without a circuit, that is to say, the difference of electric-potential between its terminals when no current can flow, which will, of course, be the total electro-motive force in any circuit of which it may form a part. The determination of this electro-motive force of each cell was therefore the first work attempted, and the committee chose as a standard of electro-motive force, that of a Daniel cell (Wiedemann pattern). It was not the business of the committee to fix the absolute value of this cell as a standard, and they therefore adopted a value nearly that generally recognized for such a cell.

The following determinations of the electro-motive force of a Daniel cell have been made by different persons:

Sir William Thomson	1·122	Volts.
Lord Rayleigh	1·072	"
Kohlrausch	1·138	"
Daniel	1·124	"
Clarke	1·11	"
Barker	1·02	"
Carhart	1·122	"
Ordinary assigned value	1·079	"

The method of determining relative electro-motive forces was such that the values obtained were simply proportional to the deflections of the galvanometer needle which were carefully read to single divisions of the scale.

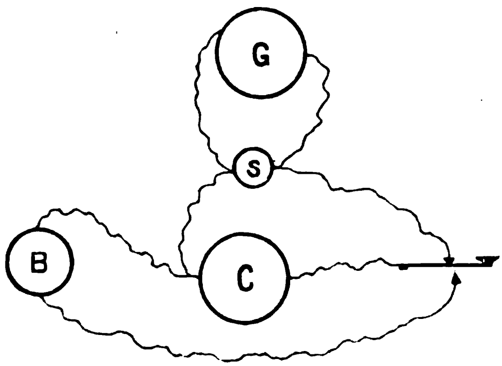
The standard Daniel cell used gave 83 divisions on the scale, while a Latimer-Clarke Standard cell made by Weston gave 110 divisions, and a Leclanche cell 118. The electro-motive force of a Clarke's Standard is to that of the Daniel as 110 to 83. Assume that of the Daniel as being 1·10 volts, and that of the Clarke cell becomes 1·457 volts which is precisely what Clarke gives for it. If Lord Rayleigh's determination of the value of Clarke's cell 1·435 volts be adopted, then that of the Daniel should be 1·082—a trifle more than that generally assigned which is 1·079.

The committee adopted 1·10 volts as being the standard of the electro-motive force of the Daniel cell and all computations have been made on that assumption. If any one would assign a different value

from the one here employed, he is furnished will all the data necessary for calculating the electro-motive force of any cell examined.

The *method* of determining the electro-motive force is as follows: The battery to be examined has its terminals touched to a condenser for an instant which becomes charged to the same potential as the cell. The condenser is then instantly discharged through a galvanometer and the deflection noted.

The accompanying diagram will serve to show the attachments and working of this method.



G, is the galvanometer; S, its shunt; C, the condenser; and B, the battery to be tested.

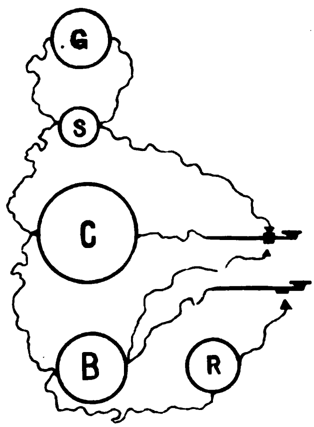
When the key is pressed down, the battery is connected to the terminals of the condenser, which becomes charged, and when the key is raised the condenser discharges through the galvanometer, and the battery is thrown out of circuit. On account of the necessary delicacy of the galvanometer, it is essential that it be used in a place not subject to vibratory movements, nor in proximity to masses of iron or magnets or electrical currents. No place about the exhibition building could be found free from these disturbances, but, through the courtesy of Dr. Barker, of the University of Pennsylvania, we were provided with all the conveniences we needed; not only with a suitable room, but with galvanometers, shunts, condenser, Wheatstone's bridge, etc. The galvanometer had a resistance of 3,732 ohms, the condenser a capacity of ½ a microfarad. An electrometer reversing key was used to discharge the condenser.

With this apparatus and arrangement, readings of the deflections were taken for each cell; seldom more than five, however, if they were uniform, which was generally the case.

Table of Electro-motive Force of Cells.

Name of Cell.	No.	Deflec.	E. M. F. (volts).	
Standard Daniel	1	83	1·1.	Assumed.
Leclanché (carbon in porous jar)	1	132	1·73.	Just set up.
" " "	2	135	1·76	"
" "Prism Cell" (zinc in porous cup)	1	118	1·54	"
" " " "	2	118	1·54	"
" " free zinc	1	118	1·54	"
" " "	2	119	1·55	"
" diamond carbon	1	110	1·44	"
" "	2	110	1·44	"
Bergman calomel cell	1	104	1·37	"
" "	2	95	1·26	"
" "	3	99	1·31	"
" "	4	99	1·31	"
" "	5	100	1·32	"
Partz's small cell	1	111	1·47	"
" "	2	106	1·40	"
" large cell	1	149	1·97	"
" "	2	134	1·77	"
" iron cell	1	74	·98	"
" medical cell	1	122	1·22	"
" " small cell	1	120	1·6	"
Flemming's modified Leclanché (portable)	1	81	1·07	
" " " "	2	110	1·46	
" Leclanché prism	1	117	1·55.	Up 4 days.
" " "	2	118	1·55	"
" cabinet	1	109	1·45	
" "	2	105	1·39	
Partz's large cell	1	149	1·97.	Up 3 days.
" "	2	134	1·77	"
" iron cell	1	74	·98	"
" medical cell	1	122	1·61	
" "	2	120	1·6	
Diamond carbon	2	94	1·24.	Up 4 days.
Siemens-Halske	1	83	1·10	
Fitch chlorine cell	1	98	1·3	
" "	2	95	1·26	
Oxide of copper cell	1	....	·90	
" " "	2	....	·76	

Batteries differ in their rate of output of electrical energy, and also in their constancy. It is true that if one knows the electro-motive force of a circuit and its resistance, he may know the strength of the current in that circuit, as that is given at once by Ohm's law; but it is also true that when a battery furnishes the electro-motive force, both the electro-motive force and the resistance of the cell change, each tending to lessen the strength of the current; and, as both fluctuate, it is of but little use to depend upon what is ordinarily called the internal resistance of the cell as being its working resistance. For instance, a certain cell has an electro-motive force of 1·75 volts on open circuit and at the same time an internal resistance of 1·19 ohms. When in circuit with 5 ohms external resistance, observations made every half-minute for two minutes, show the following increase of internal resistance, 1·19, 1·25, 1·25, 1·31, 1·45, which, of course, decreases the current. Still, as there is a wide difference between cells as to their potential, depending upon their internal resistance, which adapts them to certain kinds of work, it is desirable to know its value in order that one may know about what to expect from a given cell. Just as the electro-motive force of the cell was determined in open circuit, so the internal resistance of the cell was measured, and is as nearly as possible the resistance of the cell as a conductor.



G, galvanometer; S, shunt; C, condenser; B, battery to be measured; R, variable resistance.

Each cell was tested for its internal resistance by the same condenser method, closing the circuit of the battery through a known external resistance and without any delay discharging the condenser, which was

shunted upon the same battery terminals, the interval never being greater than a quarter of a second between the closing of the battery circuit and the discharge of the condenser. Thus the battery was not allowed to polarize appreciably.

Names of Cells.	E. M. F., open circuit.	E. M. F., closed circuit.	External resistance.	R, total resist. in circuit.	$R-r$, internal resist. in ohms.
Leclanché Disque .... No. 1.	130	109	5	6	1·
" " .... No. 2.	134	112	5	6	1·
Bergman's cells, average of 5	100	88	5	5·68	·68
Diamond Carbon .... No. 1.	94	85	5	5·53	·53
Siemens-Halske .... No. 2.	83	36	5	11·5	6·5
Partz's Large Cell .... No. 1.	149	135	5	5·51	·51
" " " .... No. 2.	134	123	5	5·44	·44
" Iron "	74	69	5	5·3	·3
" Medical " .... No. 1.	122	87	2	2·8	·8
" " " .... No. 2.	120	94	2	2·45	·45
Flemming,s Leclanché, portable	81	31	5	13	8·
" " "	111	47	10	23·5	13·5
" Cabinet Cell .... No. 1.	109	52	10	21	11·
" " " .... No. 2.	105	50	10	21	11·
Leclanché Porous Cell .... No. 1.	128	80	2·17	3·47	1·3
" " " .... No. 2.	122	80	2·17	3·3	1·3
" "Prism," zinc in porous cup .... No. 1.	115	79	2·17	3·15	·98
" " " " " " " .... No. 2.	117	79	2·17	3·12	·95
" " free zinc .... No. 1.	118	83	2·17	3	·83
" Diamond Carbon .... No. 2.	94	78	2·17	2·61	·44
Fitch's Chlorine Cell .... No. 1.	98	73	5	6·7	1·7
" " " .... No. 2.	95	61	5	7·8	2·8

As the electro-motive force is instantly distributed through the circuit, one is practically measuring the difference of potential between the terminals of a coil having a known resistance, and the electro-motive force in any part of the circuit, is to the total electro-motive force in the circuit as the resistance in the part is to the whole resistance. Let E be the total electro-motive force in a circuit, R the total resistance, e the electro-motive force between two points in the circuit

having a known resistance r, then $E : e :: R : r$ and $R = \frac{Er}{e}$. $R - r$ is the resistance of the cell. The above diagram illustrates the connections for such observations.

In order that this value of R should be the true value, it is essential that the battery circuit should not be closed long enough to permit polarization. This may be effected by so arranging the keys that both circuits may be closed by the same movement or by employing a separate key and closing the battery circuit first and as soon as possible afterwards the other, which may be done very easily within the fourth of a second, by counting "one, two; one, two"; at the rate of twice a second; closing the battery circuit on one and the condenser circuit on two, letting up both instantly; this was the method followed in this series of observations.

The known resistance in R of the diagram was generally one of the coils in a Wheatstone Bridge, and was generally considerably greater than the resistance of the cell itself.

The above table gives the electro-motive forces and resistances thus measured.

CURRENT STRENGTH OF CELLS.

The current strength in any conductor with a given resistance is determined by the difference of electrical potential between the terminals of the conductor, and varies directly as such difference of potential. Also, the fall of potential between any two points in a conductor will be proportional to the resistance between those points. It follows that the current strength in a coil may be accurateiy determined by measuring the resistance of the coil and the difference of potential at its terminals. The resistance of a coil of wire may be measured with very great precision, and the difference of potential by the method described is accurate to two decimal places when the readings are to single divisions on the scale, which we deemed sufficiently close for this purpose.

By observing the deflection produced by the condenser with open circuit, one determines the total electro-motive force of the circuit, by observing the deflection produced on any closed circuit, one determines the relative electro-motive force between the points chosen. In the present instance the external resistance was generally 2·17 ohms, it being made up of a galvanometer coil having a resistance of ·56 of

an ohm and a small free coil with a resistance of 1·61 ohm. As the electro-motive forces are proportional to the deflections, and the resistance external to the cell is constant, the current strength is proportional to the deflections. When observations are made at intervals for several minutes the difference of potential is generally found to fall, owing chiefly to the increase of resistance in the cell. The following table gives the strength of current in ampères furnished by each cell named, for a time given in minutes indicated. The external resistance being, as already stated, 2·17 ohms generally.

This table has nothing to say as to the life of a cell. There was not time enough at the disposal of any member of the Committee to run each cell down to its minimum working capacity. In order to do such work, it would be necessary to have duplicate apparatus for observations, and days would have been needed for some single cells, such as Partz's. Neither does the table indicate the rate of recovery of a cell after use, but it gives reliable information as to the available current from a given cell on such a short circuit as was employed here, and in general it is true that a cell will maintain a degree of constancy the greater the resistance it is worked through. Of course, if the cell is used so long or so vigorously as to materially change the chemical constitution of the acting liquid, the electro-motive force will suffer reduction, and there is no time rate that can be applied with any degree of accuracy. It is also to be remarked that when cells are coupled serially for working, the electro-motive force available in the circuit will not be the product of the electro-motive force of one cell into the number of cells, but a fraction of that which will vary with the number of cells in circuit, the loss being about one volt for fifteen volts; and fifteen or twenty for one hundred volts, and this, too, with fair insulation.

*   *   *   *   *   *   *   *   *

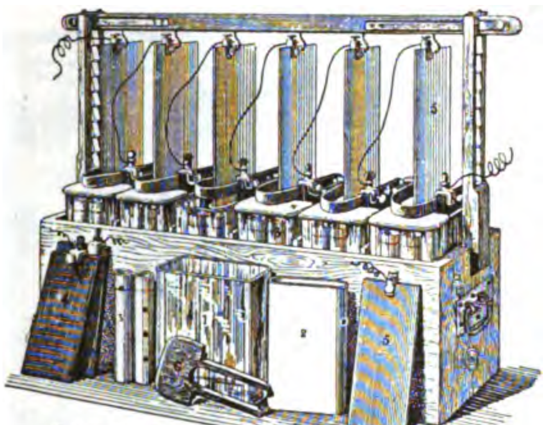
James W. Queen & Co. exhibited a battery cell called the *Chloris Baudet,* which for some reason failed to reach the examiners at the time the other cells were examined, and not being disposed of, on account of its high cost it was soon sent back to Paris. On account of the claims made for this cell it was thought best to construct one and test it. The cut represents one of these batteries of six cells. It is called an unpolarizable battery on account of its constancy of action. The following is a description of the cell by Baudet. The outer rectangular cell I, 22 cm. by 18 × 9. A porous cell 2, for the

Current Strength, in Amperés, at Intervals in Minutes.

Names of Cells.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30	40	50	60
Partz Cell........No. 1.	·70	......	......	......	......	·68	......	......	......	......	·67	......	......	......	......	·66	·65	·64	·63	·61	......	......
" " ....No. 2.	·66	......	......	......	......	·64	......	......	......	......	·62	......	......	......	......	·60	·59	·59	·58	·56	·54	·53
" Iron Cell........	·26	......	......	......	......	·25	......	......	......	......	·25	......	......	......	......	·25	·25	·25	......	·25	......	......
Leclanché Porous Cell, No. 1.	·48	......	·48	......	·47	......	·46	......	·45	......	·45	......	·14	......	......	......	......	......	......	......	......	......
Leclanché Porous Cell, No. 2........	·48	......	·48	......	·47	......	·47	......	......	......	......	·46	......	......	......	......	......	......	......	......	......	......
Leclanché Prism, zinc in porous cell	·47	......	·43	......	·42	......	·41	......	·40	......	·40	......	·40	......	......	·39	......	......	......	......	......	......
Leclanché Prism, zinc in porous cell........	·47	......	·46	......	·43	......	·41	......	·41	......	·40	......	·40	......	·39	·38	......	......	......	......	......	......
Leclanché Prism, free zinc........	·49	......	·47	......	·47	......	·46	......	·45	......	·45	......	·43	......	·43	......	......	......	......	......	......	......
Leclanché Diamond Carbon........	·47	......	·43	......	·40	......	·39	......	·38	......	·36	......	·35	......	·34	·34	......	......	......	......	......	......
Bergman's Calomel	·41	·40	......	·39	......	·39	......	·39	......	·39	......	......	·39	......	......	......	......	......	......	......	......	......
Siemens and Halske...	......	......	·16	......	·14	......	·14	......	·14	......	·14	......	......	·14	......	......	......	......	......	......	......	......
Flemming's Cabinet...	·12	......	·09	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
" Portable.	·13	·09	......	·07	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
Partz Open Circuit......	·30	......	·28	......	......	·27	......	·25	......	·23	......	......	·21	......	·19	......	......	......	......	......	......	......
" Medical Cell......	·42	......	·39	......	·31	......	·27	......	·24	......	......	......	......	......	......	......	......	......	......	......	......	......
Fitch's Chlorine........	·29	......	......	......	·32	......	......	·33	......	·34	......	......	·34	......	......	·34	......	......	......	......	......	......

zinc plate 5. Two porous jars 3, one for crystals of bichromate of potash, the other for sulphuric acid; one with holes and the other without; two plates of carbon 4, each with suitable wire connections, and a suitable cover 6, for the whole, to maintain the points in their places. The solutions consist of a saturated solution of bichromate of potash, with sulphuric acid as for the ordinary bichromate battery for the outer jar containing the carbon, and a super-saturated solution of acid sulphate of potash $KHSO_4$, for the porous jar containing the zinc. The undissolved sulphate may remain in the bottom of this porous jar. Common salt may be used as a substitute for the potassium sulphate.

Batterie de 6 Eléments Impolarisables



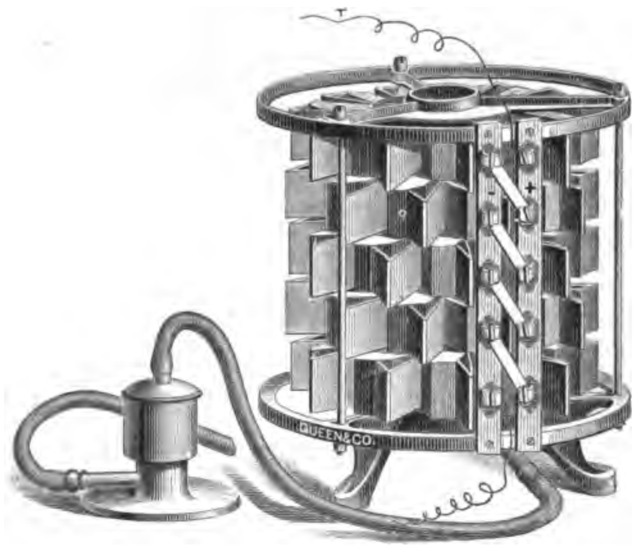
Pile Impolarisable
de CLORIS BAUDET

In the cell constructed for the test, the bi-sulphate of potash was used in the porous jar. When first set up, this cell had an electro-motive force of 1·87 volts. It was then put in short circuit with an external resistance of 5·8 ohms, including the galvanometer, when the deflection was 47°, with a current of ·262 ampères. As the constant of the galvanometer was ·245, it followed that the internal resistance of the cell was 1·3 ohms, which is a small resistance for a cell for constancy, but the immersed zinc was but about 3 inches of a half inch rod. The needle fell one degree in the first five minutes, where it remained for an hour, when it rose to 47½°, where it stood steadily for five hours; the next morning it was at 45°. It remained practically constant for

about 28 hours, when it suddenly fell; evidently some of the material had been used up. This is a surprisingly good record for a cell, and surpasses the Grove; the Bunsen, or the common bichromate cells a long way.

THERMO-ELECTRIC BATTERIES.

Jas. W. Queen & Co. exhibited two of the modern thermo-batteries, one of Clamond and two of Nöe-Rebicek. The Clamond consisted of pairs of iron and an alloy of bismuth and antimony, arranged in rings. There were 14 rings of 11 pairs each; 154 pairs. This was found to give an electro-motive force of 3·02 volts, and to have while hot an internal resistance of 2·2 ohms.



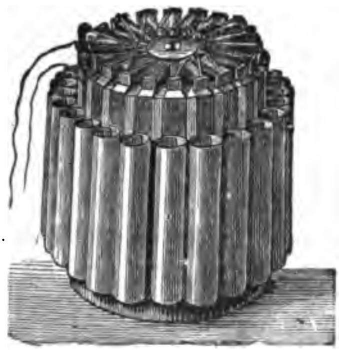
Clamond Thermo-Electric Battery.

The following is the statement of the maker of the Clamond batteries:

No. of Elements.	E. M. F. in Volts.	Int. Resist., ohms.	Gas per hour required.
50	1·8	·3	250 litres.
100	3·6	·6	450 "
150	5·4	2·	350 "

The Nöe-Rebicek thermo-piles consisted of twenty pairs of German silver and an alloy of zinc and antimony. One of the specimens had

twice the cross-section of the other one. The larger had an electromotive force of 1·94 volts, or nearly one-tenth of a volt per pair. The smaller one gave 1·73 volts. The internal resistance of the larger was ·5 ohm, and of the smaller ·8 ohm. The Nöc-Rebicek battery has the highest E. M. F. of any thermo-battery that has been made on a commercial scale, and seems a long step away from the ordinary bismuth-



antimony pile, and towards a thermo pile that may be used as a substitute for the common galvanic battery. They are made of 20 elements each for a single pile, or as the substitute for a single battery cell, and any number of them may be combined, as is the case with battery cells, and arc and incandescent lighting effected or other electrical work done with them. They may be heated by gas or alcohol flame.

A. E. D.

In Mr. A. Partz's large cell he employs a plate of carbon, half an inch in thickness and three inches wide, divided by saw-cuts into six vertical prisms of half-inch sectional area. He claims that this form gives a stronger and more constant current than a closed plate, and in accordance with his desire the following test was made:

Two similar plates of half inch carbon were obtained, and one of them was divided by sawing into half inch prisms which were left united at the ends. These plates were successively coupled with the same plate of zinc and immersed in a solution of potassium pyrochromate and sulphuric acid. The current strength was measured by the aid of a delicate ampèremetre with an unvarying resistance interposed.

The following figures show the ratios of the strengths of current under these circumstances:

	Closed plate.	Open plate.
On closing circuit	1·25	1·30
After one minute	1·10	1·15
After two minutes	1·075	1·125
After three minutes	1·05	1·10
After four minutes	1·0375	1·10
After five minutes	1·025	1·10

W. H. G.

REPORT ON POROUS CELLS.

Made and Exhibited by J. E. Jeffords & Co., 1412 *Salmon Streets, Philadelphia.*

The two cells tested were of the same size, about 3 × 8 inches, and differed in color only, so far as could be seen. One cell was of white ware, and the other of a light buff ware.

Resistance was determined in a solution of copper sulphate, the cells being filled to the level of the surrounding solution. The height of liquid in each case was six and three-sixteenths inches. The results were

	White.	Buff.
Time to wet through with water	3½ min.	5½ min.
Fall of water by leakage in forty-eight hours	2 3/16 in.	1¾ in.
Resistance in ohms, of 6 3/16 inches in height	·69	1·14

F. C. VAN D.

TESTS OF SECONDARY BATTERIES.

As soon as practicable after the organization of the section for the consideration of secondary batteries, a copy of the following scheme was addressed to each of the three parties making an exhibit of such batteries. The conditions were accepted by the *Railway Light and Power Company*, and by the *Brush Company*, but the parties exhibiting the *Star Battery* declined having their battery examined, and ignored the communication of the examiners.

SCHEME PROPOSED FOR THE EXAMINATION OF SECONDARY BATTERIES.

The tests for secondary batteries will be confined to efficiency, and no report will be made on duration.

"Exhibitors will be required to furnish batteries in first-class condition, and the size, thickness of plates, and distance between them will be measured. The composition of liquid used must be stated to the examining committee, and it is desirable that the manner of preparing plates shall be made known.

The batteries will first be charged with a current of whatever strength may be designated by the exhibitor, and will be allowed to run down through their normal external resistance until the electro-motive force, as shown by the weakest cell, begins to diminish. The discharging will then be stopped, and the battery will be recharged, and at intervals of fifteen minutes the counter electro-motive force of the battery and the strength of current will be measured. When the battery is fully charged, as shown by disengagement of gas, an artificial resistance equivalent to that for which it is claimed the battery is adapted, will be substituted for the dynamo at the charging terminals, and the battery will be allowed to run down as before measuring at intervals of fifteen minutes the electro-motive force, and the strength of current until the electro-motive force begins to fall rapidly.

After making these tests the batteries will be again charged, under conditions identical with the first, and will be sealed for two, three or more days, as may be found practicable by the examining committee, after which they will be discharged through a resistance identical with the first, and the loss of energy due to standing, will be determined. If time be sufficient, the committee will measure the internal resistance of each battery.

Reports will indicate the size, thickness and number of plates, their distance apart, the composition of liquid employed, the number of cells, the weight of battery, the counter electro-motive force, the ampère-hours required for charging, the ampère-hours in discharging through the measured resistance for which it is stated the battery should be efficient, the loss of energy between charging and discharging, and the loss of energy occasioned by allowing the battery (charged) to remain idle during stated intervals of two, three or more days as may be found practicable by the committee."

The instruments used in the measurements were an Ayrton and Perry ammeter, a Carpentiers' voltmetre, and an Ayrton and Perry voltmetre. The ammeter was placed as near as practicable to the battery, and so arranged that it remained in the circuit during both charging and discharging. The voltmetre was in a short circuit connecting with the poles of the battery, measuring the counter electro-motive force during charging, and the direct electro-motive force of the discharge during which the resistance, consisting of a number of incandescent lamps in parallel circuit, was practically substituted for the machine used in charging. The committee had resolved to discharge the batteries through an invariable resistance of German silver ribbon or wire, but finding that it would be obliged to have the apparatus constructed at its own expense, it was compelled to adopt the incandescent lamp resistance as the only feasible one.

Notwithstanding all efforts it could not succeed in having the ammeter calibrated until after the termination of the actual measurements. The calibration then obtained was far from satisfatory, as it covered only a portion of the scale of the instrument, but it appeared to indicate that the actual readings were slightly lower than they should have been in the upper degrees of the scale. A recalculation of the results with these corrections introduced made it appear probable that the efficiencies found and given further on are about one per cent. too low. However, as the Committee is not perfectly satisfied with the corrections, and as the practical difference is quite small, it has not been deemed advisable to use other figures than those given by the direct readings of the instrument.

The battery tested for the Railway Light and Power Company, consisted of thirty-four cells, each 11 by 12 by 3 inches, containing four plates each, 9 by 10 by $\frac{3}{16}$ inches. The plates are formed by Faure's process, red lead being compressed into an excavated surface. This battery was charged by a Weston dynamo, and was used at the Exhibition to run six or eight incandescent lamps of different resistances.

It was discharged by the committee on the evening of the 8th October, until the electro-motive force at the poles on closed circuit was 44·14 volts, and was recharged and again discharged between the morning and night of the following day. The installation of the battery was very bad. The connections between the plates were made by lead bolts which could not be properly tightened, and the battery was placed on a carpet which was kept continually moist by the acid spray thrown

up by the bubbles of gas produced towards the close of the chargings. These faulty conditions may account for the low efficiency found for the battery.

The discharge was effected through a resistance consisting of sixteen Weston lamps. When the discharge was stopped on the 8th October, the electro-motive force on closed circuit was 44·14 volts, on open circuit 53·5 volts. On the 9th October, after verifying the electro-motive force, the battery was charged with 299376·825 volt-ampère-minutes. The discharging was then begun, and an energy representing 159659·649 volt-ampère-minutes had been expended in the lamp resistance before the electro-motive force on closed circuit had fallen to 44 volts.—the potential at the poles while the battery was doing work at the close of the discharge in the morning.

The efficiency of the battery was therefore

$$\frac{159659{\cdot}649}{299376{\cdot}825}$$

or 53·66 per cent. in its delivery of energy compared with the energy required for charging.

The fall of potential in this battery was very unevenly distributed among the cells. On beginning the discharge at 5.30 P. M., on the 9th October, the electro-motive force of the separate cells was uniformly 1·9 volts. Between this time and 7.15 P. M., the electro-motive force of the battery fell from 64·2 to 60·19 volts, the potential of the separate cells taking equal part in the fall. At 7.30 a difference in potential became apparent among the cells, and the electro-motive force began to fall rapidly. One cell was at 0 potential at 8 o'clock, three at 8.15, four at 8.30 and five at 9.10, while the electro-motive force of the other cells was but little below that at starting the discharge.

As may be seen in the tabular statement, the battery was charged during four hours and forty-eight minutes, at the average rate of 1039·5 volt-ampères. It yielded during discharge for four hours and ten minutes the average rate of 638·6 volt-ampères.

From 786·45 volt-ampères, which was maintained sensibly constant during the first hour, the delivery fell to 699·36 at the end of the second hour, 557·57 at the end of the third, and 416 at the end of the fourth.

The results of the first test of this battery convinced the committee that the cells were in such a condition that any further measure-

ments and tests for holding charge would be entirely devoid of scientific interest, and of no benefit to the Institute or the exhibitors.

Tabular Statement of Observations and Results of Calculations of Tests made on Secondary Battery exhibited by the Railway Light and Power Company, 9*th October*, 1884.

Time of observation.	Dif. of potential at poles. *Volts* = E.	Current, ampères = C.	E × C, volt-ampères.	Mean E × C, between observations.	Total energy of charge, E × C × minutes.
10.42 A.M......	77·6	10·5	814·800	....	....
11.00.................	77·6	13·0	1008·800	911·800	16412·400
11.15.................	77·6	14·0	1086·400	1047·600	15714·000
11.30.................	77·6	14·0	1086·400	1086·400	16296·000
11.45................	77·6	12·0	931·200	1008·800	15132·000
12.00 M............	78·9	13·0	1025·700	978,450	14676·750
12.15........	78·9	13·5	1065·150	1015·425	15681·375
12.30.......	80·25	14·0	1123·500	1094·325	16414·875
12.45.................	80·25	14·5	1163·625	1143·562	17153·438
1.00 P.M..	80·25	15·0	1203·750	1183·688	17755·312
1.15.................	80·25	14·5	1163·625	1183·688	17755·313
1.30.................	81·59	14·0	1142·260	1152·942	17294·137
1.45.................	80·25	12·0	963·000	1052·630	15789·450
2.00.................	81·59	12·25	999·478	981·238	14718·581
2.15.................	82·9	12·5	1036·250	1017·864	15267·956
2.30.................	81·59	12·0	979·080	1007·665	15114·975
2.45.................	81·59	11·75	958·682	968·881	14533·219
3.00.................	81·59	10·5	856·695	907·689	13615·331
3.15.................	82·9	13·0	1077·700	967·197	14507·963
3.30.................	82·9	12·0	994·800	1036·250	15543·750
					299376·825

Time of charging, 4 hours 48 minutes. Average rate of charging = 1039·5 volt-ampères.

Discharging through Sixteen Weston Lamps.

Time of observation.	Dif. of potential at poles. Volts = E.	Current, ampères = C.	E × C, volt-ampères.	Mean E × C, between observations.	Total energy of discharge. E × C × minutes.
5.30 P.M.	64·2	12·25	786·450	....	....
5.45	64·2	12·25	786·450	786·450	11796·750
6.00	64·2	22·25	786·450	786·450	11796·750
6.15	63·13	12·25	773·342	779·896	11698·444
6.30	62·86	12·0	754·320	763·831	11457·469
6.45	62·86	12·0	754·320	754·320	11314·800
7.00	61·53	11·75	722·978	738·649	11079·731
7.15	60·19	11·75	707·232	715·105	10726·575
7.30	58·85	11·75	691·488	699·360	10490·400
7.45	58·85	11·75	691·488	691·488	10372·312
8.00	56·18	11·0	617·980	654·734	9821·006
8.15	53·5	10·75	575·125	596·553	8948·288
8.30	52·43	10·3	540·020	557·577	8363·655
8.45	49·76	10·0	497·600	518·814	7782·218
9.00	49·49	9·25	457·782	477·691	7165·369
9.10	47·08	9·25	435·490	446·636	4466·362
9.20	46·01	9·2	423·292	429·391	4293·910
9.30	45·48	9·0	409·320	416·306	4163·060
9.40	44·14	8·5	375·190	392·255	3922·550
					159659·649

Time of discharging, 4 hours 10 min's. Average rate of discharge = 638·6 volt-ampères.

$$\text{Efficiency} = \frac{159659 \cdot 649}{299376 \cdot 825} = 53 \cdot 66 \text{ per cent.}$$

The secondary battery tested for the Brush Electric Company consisted of nineteen cells, each containing three plates 16 by 16 inches, the total weight of lead per cell being about one hundred pounds. These plates are said to be formed by the Planté's process, alternating currents being passed between cast lead plates immersed in dilute sulphuric acid. The cells were in good condition and the connections of the plates were soldered.

The Carpentier volt-meter used was calibrated by this battery, and the readings being 1·91 volts per cell throughout the whole scale employed, may be considered sufficiently exact.

On the 12th of October the battery was discharged through 41 Swan lamps in parallel circuit, until the difference of potential at the terminals had fallen to 29 volts, the current flowing being then 38·25 ampères. Before starting to recharge on the 13th of October, the electro-motive force on open circuit was 36·3 volts, and with 40 lamps in the circuit 29·8 volts. The recharging was then begun at 9 A. M., and was continued until 10 P. M. of the same day, with an interruption of fifty-nine minutes due to an accident to the engine.

After charging the battery it was discharged through 43 lamps. The electro-motive force on open poles was 38 volts; with the lamps in circuit 34 volts. The current passing through the lamps was 46·75 ampères.

As will be seen in the accompanying table, 562202·25 watts were required to charge the battery from a potential of 29 volts on closed circuit, while in discharging down to the same point 390454·625 watts were obtained. The efficiency ratio is therefore

$$\frac{390454·625}{562202·250}$$

or 69·45 per cent.

Appended are graphic expressions of the rise and fall of potential during charging and discharging, and of the energy absorbed and delivered by the battery. The curves and the columns of the table showing the fall of potential and the energy obtained from the battery, indicate that while there is a gradual weakening of the whole battery, the principal falling off is due to the sudden weakening of individual cells, and that the latter do not run down uniformly.

The test of the Brush secondary battery was sufficiently severe, as the charging was done with a somewhat heavier current than is usually recommended for the purpose, and the discharging was at an exceedingly rapid rate. It was therefore decided that after the test for holding charge had been made the battery should be recharged and discharged through a smaller variation in electro-motive force, but at a slower rate.

The battery was recharged on the 16th of October and locked up by the committee who held the keys for ten days. In the mean time we had been requested to return the instruments which had been placed at our disposal. As the Franklin Institute authorities could not guarantee that the instruments would again be placed in our hands for the resumption of the tests before the battery was required to be moved,

the committee decided that it was not advisable to prolong work for which the facilities had been withdrawn. With the consent of the Brush Company, further tests were therefore abandoned.

Tabular Statement of Observations and Calculated Results of Charging Brush Secondary Battery, 13th October, 1884.

Time of Observation.	Dif. of potential at poles. *Volts* = E.	Current passing through battery. *Amperes* = C	E × C. Volt-ampèr	Mean E × C between observations.	Total energy of charge. E × C × minutes.
9.00 A. M.	39·5	19·5	770·250	....	....
9.15	40·5	19·0	769·500	769·875	11548·125
9.30*	37·5	Engine stopped.	769·500	769·500	7695·000
10.24	39·5	19·75	780·125	....	....
10.30	40·5	20·00	810·000	795·063	4770·375
10.45	40·25	19·75	794·938	802·469	12037·031
11.00	40·0	19·75	790·000	792·469	11887·031
11.15	40·0	19·75	790·000	790·000	11850·000
11.30	39·75	19·25	765·187	777·594	11663·906
11.45	39·75	19·25	765·188	765·187	11477·813
12. M	39·5	19·25	760·375	762·781	11441·719
12.15	39·5	19·0	750·500	755·437	11331·562
12.30	39·25	19·0	745·750	748·125	11221·875
12.45	39·25	18·75	735·937	740·844	11112·656
1.00 P. M.	39·25	18·75	735·938	735·938	11039·063
1.15	39·0	18·5	721·500	728·719	10930·781
1.30	39·25	18·75	735·937	728·719	10930·781
1.45	39·25	18·5	726·125	731·031	10965·469
2.00	39·25	18·5	726·125	726·125	10891·875
2.15	39·25	18·5	726·125	726·125	10891·875
2.30	39·25	18·5	726·125	726·125	10891·875
2.45	39·25	18·5	726·125	726·125	10891·875
3.00	39·5	19·0	750·500	738·312	11074·688
3.15	39·5	19·0	750·500	750·500	11257·500
3.30	39·25	19·0	745·750	748·125	11221·875
3.45	39·5	19·0	750·500	748·125	11221·875
4.00	39·5	19·0	750·500	750·500	11257·500
4.15	39·5	19·0	750·500	750·500	11257·500
4.30	39·6	19·25	762·300	756·400	11346·000
4.45	39·7	19·25	761·225	763·263	11448·937
5.00	39·7	19·0	754·300	759·262	11388·938
5.15	39·6	19·7	780·120	767·210	11508·150
5.30	39·8	19·6	780·080	780·100	11701·500
5.45	40·0	19·6	781·000	782·040	11730·600
6.00	40·25	19·6	788·900	786·450	11796·750
6.15	40·25	19·6	788·900	788·900	11833·500
6.30	40·5	19·7	797·850	793·375	11900·625
6.45	40·5	19·65	795·825	796·838	11952·563
7.00	40·75	20·0	815·000	805·412	12081·187
7.15	41·0	19·8	811·800	813·400	12201·000
7.30	41·2	19·5	803·400	807·600	12114·000
7.45	41·6	19·75	821·600	812·500	12187·500
8.00	42·0	19·6	823·200	822·400	12336·000
8.15	42·0	19·5	819·000	821·100	12316·500
8.30	42·5	20·0	850·000	834·500	12517·500
8.45	43·0	19·5	838·500	844·250	12663·750
9.00	43·5	19·5	848·250	843·375	12650·625
9.15	44·5	19·0	845·500	846·875	12703·125
9.30	45·0	19·0	855·000	850·250	12753·750
9·45	46·0	19·0	874·000	864·500	12967·500
10.00	47·0	19·25	904·750	889·375	13310·625
	40·56	19·26			562202·250

* Engine stopped from 9·25 to 10.24.

Total time of charging, 12 hours 1 minute. On open poles at 9 A. M. = 36·8; at 10 P. M. = 39·0.

Tabular Statement of Observation and Calculation of Results of Discharging through Incandescent Lamp Resistance, Brush Secondary Battery, 13th and 14th October, 1884, immediately after charging.

Time of Observation.	Dif. of potential at poles. *Volts = E.*	Current. *Amperes = C.*	E × C. Volt-ampères	Mean E × C between observations.	Total energy of discharge. E × C × minutes.
10·47 P. M.	34·0	46·75	1589·500	....	....
11·00	34·0	46·75	1589·500	1589·500	20663·500
11·15	33·5	46·75	1566·125	1577·813	23667·188
11·30	33·5	46·75	1566·115	1566·125	23491·875
11·45	33·25	46·5	1546·125	1556·125	23341·875
12·00	33·25	46·5	1546·125	1546·125	23191·875
12·17	33·2	46·25	1535·500	1540·812	26193·812
12·30	33·0	46·0	1518·000	1526·750	19847·750
12·45	33·0	45·5	1501·500	1509·750	22646·250
1·00 A. M.	33·0	45·0	1485·000	1493·250	22398·750
1·15	32·5	45·0	1462·500	1473·750	22106 250
1·30	32·0	44·25	1416·000	1439·250	21588·750
1·45	32·0	44·0	1408·000	1412·000	21180·000
2·00	31·5	43·5	1370·250	1389·125	20836·875
2·15	31·25	43·0	1343·750	1357·000	20355·000
2·30	31·0	42·0	1302·000	1322·875	19843·125
2·45	30·5	41·25	1258·125	1280·063	19200·938
3·00	30·0	40·25	1207·500	1232·812	18492·187
3·15	29·25	39·0	1140·750	1174·125	17611·875
3·18	29·0	38·75	1123·750	1132·250	3396·750
	32·135	44·188			390454·625

Total time of discharge, 4 hours, 31 minutes.

$$\text{Efficiency} = \frac{390454{\cdot}625}{562202{\cdot}250} = 69{\cdot}45 \text{ per cent.}$$

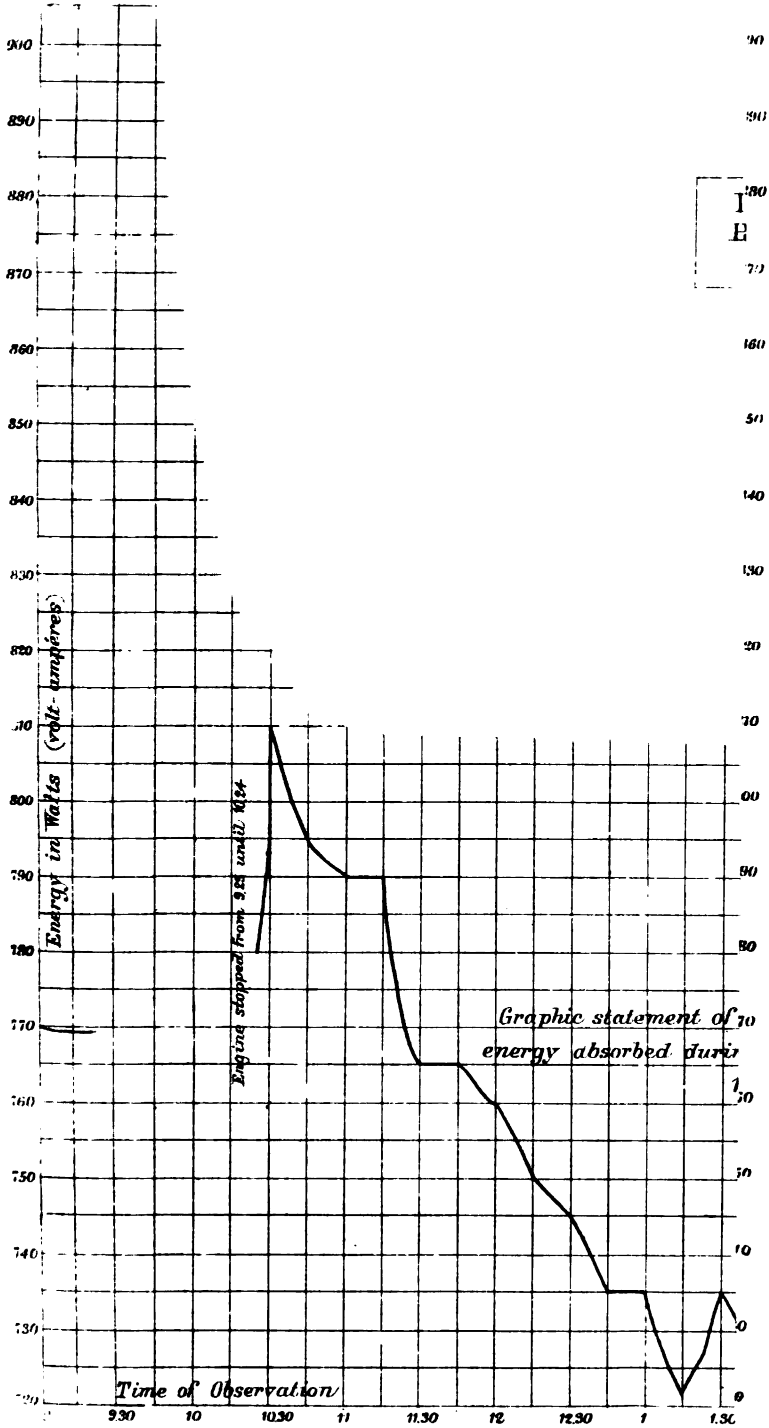
Reported by WM. H. GREENE, and F. C. VAN DYCK.

Adopted by the Section.

F. C. VAN DYCK,
Chairman Section XIV.

A. E. DOLBEAR, SAMUEL P. SADTLER,
WM. DRYSDALE. WALTER M. JAMES,
WILLIAM H. WAHL.

WM. H. GREENE,
Secretary Section XIV.


Energy in Watts (volt-ampères)
Engine stopped from 9.25 until 10.24
Graphic statement of
energy absorbed durir
Time of Observation
900
890
880
870
860
850
840
830
820
810
800
790
780
770
760
750
740
730
720
9.30
10
10.30
11
11.30
12
12.30
1
1.30

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

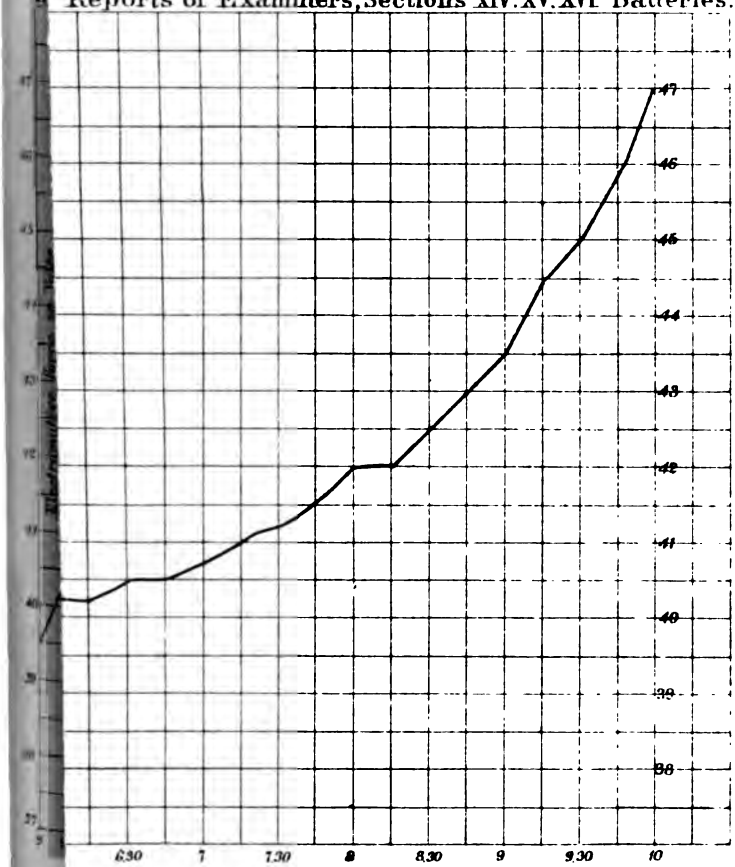
OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS

Reports of Examiners, Sections XIV.XV.XVI. Batteries.



1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORT OF EXAMINERS

—OF—

SECTION XVIII.

(SECTION II., CLASS IV. OF THE CATALOGUE.)

UNDERGROUND CONDUITS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, FEBRUARY, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

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COLEMAN SELLERS,

WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XVIII.—UNDERGROUND CONDUITS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XVIII, on Underground Conduits.

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The following report of the Examiners in Section XVIII (on Underground Conduits), is respectfully submitted.

F. D. DE WOLSKI (*Ch'n*),

Examiners of Section XVIII.

PREFACE.

In submitting a report on the various underground conduits exhibited at the International Electric Exhibition the undersigned Examiners desire to mention that their task would have been a much easier one had each exhibitor furnished them at the outset with a brief practical description of his system. In fact few of them did themselves justice in this respect.

The undersigned carefully examined the models, in the presence, as far as possible, of the exhibitors themselves, and some of the members inspected the systems in practical operation in the city of Philadelphia. They regret they were unable to carry out any system of tests owing to want of time and absence of facilities.

A programme was drawn up by Dr. Frazer, and approved by the Section, to assist the examiners in framing their individual reports on each system, and will be found attached to this report.

Although the examiners abstained as far as possible from entering into the comparative merits of the systems, the examiners considered it advisable to note the obvious merits and demerits of each system, so far as they had means of judging. The points upon which they have commented are such as a sufficient experience of analagous contrivances enabled them to judge of from the bare statements and descriptions. In no case was it possible to state from actual observation of the working of any of these systems, that they did or did not fulfil what was claimed for them.

Your examiners are of the opinion that during the experimental stage of underground conduit construction for electric currents, it is desirable, in the interest of the community in which such conduits are laid, that the latter be capable of use for as many different purposes, and by as many different companies as possible: and also be capable of inspection in every part, and removal or replacement with the greatest possible rapidity, and the least possible obstruction to the public highways.

The rapid advance of electrical science in the past renders it nearly certain that the next few years will witness great changes in the methods for the production and distribution of this form of energy; and with an unelastic system in which a corporation may have expended large sums of money, the practical advantages of the introduction of electricity may be entirely dissipated for a long time. For the same reason it seems to the undersigned unadvisable at the present time for a corporation to adopt any style of plant which is adapted only to one system of distribution, however excellent the system may seem to be.

They feel impelled to add one final word in view of the doubt that has been expressed as to the feasibility of constructing underground conduits for all purposes of electrical distribution. Certainly, at least, within the limits of large cities, whether or not it be found in the future to be desirable to enclose telephone and telegraph, with light and power circuits; or any two of the foregoing in the same conduit, they express no opinion, but that the electric current for any and all of these purposes can be successfully transmitted underground, there is not the least reason to question.

They believe that a careful series of tests, made by competent experts, on the systems already laid, would be of great value to science, and to all those who are interested in the use of the electric current.

ALPHABETICAL LIST OF THE EXHIBITS VISITED BY THE COMMITTEE.

(SECTION XVIII.)

The exhibits mentioned here do not include all of those mentioned in Section II., Class IV. of the catalogue. Some of these latter do not properly belong to the "underground" class; some of them were not found by the committee, and some had no one to explain them, and no printed or written descriptions which could be procured.

For one or more of these reasons the undersigned examiners have been obliged to omit mention of some exhibits which are classed in the catalogue under the head of Section II., Class IV.

(Form of sheet with blanks prepared for the use of members of the Section.)

INTERNATIONAL ELECTRICAL EXHIBITION

OF THE

FRANKLIN INSTITUTE,

September and October, 1884, at Philadelphia.

Programme for Examination, by Section XVIII. of the Board of Examiners,

IN SECTION II., CLASS IV.

OF THE CATALOGUE.

(UNDERGROUND CONDUITS FOR ELECTRIC CONDUCTORS.)

DIVISION OF THE WHOLE SUBJECT.

A.—Advantage or disadvantage to those using currents.
- a. Electrodes permanently sealed.
- b. Electrodes capable of being inspected at every part.

B.—Advantage or disadvantage to the communities at large.
1. In city streets.
2. Adaptability for different companies to use in common.
3. Relative supply.

C.—Systems undeveloped or partially developed.

Members of the Section are requested to fill up as many as possible of the blanks for as many as possible of the exhibits, and to forward their notes to the Chairman of the Section, Captain de Wolski, at the building.

HOW DO THE SEVERAL EXHIBITS STAND WITH RESPECT TO THE FOLLOWING PARTICULARS?

(a.)—Electrodes permanently sealed.

(b.)—Electrodes capable of being inspected at every part.

1. Preservation of insulation.
2. Expense of insulation per unit of length.

3. Avoidance of induction.
4. Speed of signalling; *i. e.*, capacity for rapidity of charge and discharge of conductor.
5. Cheapness of plant and maintenance.
6. Ease and cheapness of laying and taking up.
7. Facility for expansion. (Increase in number of conductors singly or by groups.)
8. Rapidity of repair.
9. Durability.
10. Safety of wires from stroke by lightning.

EXHIBITS OF UNDERGROUND CONDUITS FOR ELECTRICAL CONDUCTORS.

(From the Official Catalogue, page 79.)

Continental Underground Cable Co. Models of Underground Conduits. (No. 5, North Gallery.)

Woodward, Jas. S., Phila. Woodward's Curb Conduit for Electric Conductors and Steam Heating Pipes. (North Gallery.)

Hendley, Wm., Washington, D. C. Wooden Conduit for Electric Conductors. Water-color illustration of above conduit system. (East Gallery.)

American Underground Electric Wire Co., New York City. Howe system for insulating electric conductors and cables, applicable to underground systems. Apparatus for designating wires in conduit systems. (West Gallery.)

The Anderson Conduit. (North West Gallery.)

American Sectional Electric Underground Co., Phila., Pa. Underground conduits and man-holes with telegraph, telephone, and electric light and power wires, showing this system of underground conduits for electric wires in operation. (L. 11–15.)

Edison, Thos. A., New York. Samples of Underground Conducting System, employed by the Edison Company. (N. 3–6, S. 3, U. 6, A. 3–6, D. 3–6.)

The Edison Exhibit of the Combined Edison Companies, New York City. Edison System of Underground Electric Conductors, with junction boxes, couplings, etc. Insulating compound. Insulating tape. (See above.)

Brooks, David, Philadelphia, Pa. The Brooks System of Underground Conduits for Electric Conductors. (Main Building, U. 14.)

National Underground Electric Co., of Newark, N. J. Full-sized model of the Conduit for Telegraph, Telephone and Light Wires, with testing station, etc. (Depot South Porch.)

Cosmopolitan Underground Telegraph, Telephone, and Electric Light Co., Camden, N. J. (Annex.)

Continental Underground Cable Co., Camden, N. J. System of underground conduits for electric conductors, including electric railway through centre of conduit for transmission of mail, packages, etc. Pipe System of Underground Conduits. (Annex.)

Union Electric Underground Co., Chicago, Ill. Conduit for Electric Light, Telegraph and Telephone Wires. Insulation and ground connection for wires. Machines for introducing wire into insulating tube. (Depot, N. Porch.)

THE AMERICAN SECTIONAL UNDERGROUND COMPANY.

("*A. b.*" *of Section's Classification.*)

This system consists of cast iron conduits, built up in sections break ing joints; the joints being secured with clamps and keys, and cement or other packing. All parts of each particular size are interchangeable. The conduit contains interchangeable metallic shelves and partitions, dividing it into compartments for carrying wires of different kinds.

Three sizes of conduit were exhibited, each being connected to a manhole placed at every street corner, into which one or more men can enter for the purpose of hauling in the wires, making the necessary connections, etc. There are further, at convenient distances along the line of conduit, handholes for tapping the wires for house-to-house supply. As the position of these is accurately known, by opening up a few stones in the pavement a wire or wires can be tapped for house supply. This is effected by running the wires required from the nearest manhole on the upper or local shelves.

Different companies can be supplied with separate compartments, and they can employ any particular insulation they prefer.

It is claimed for this system that "a metallic contact between the insulation of all wires and the earth grounds all leaking or induced currents, overcomes induction to a great extent, and renders harmless a cross in an electric light current. Further, that by the use of the copper shelves, in conjunction with telephones on metallic circuits, there is absolutely no interference whatever."

The committee was unable to satisfy itself on all these points.

The conduit when opened appeared to be very dry. It is stated that all condensation of moisture in the conduit takes place only under the manhole covers, which are exposed to the external air. This seems to be borne out by observations on the 9th of October, 1884, no rust being visible.

This system seems to meet, in a very complete way, the question of house-to-house supply; separation of wires; facility of laying; repairs; and future expansion. It is not necessary to lay the wires in the conduit until absolutely required. It would, however, be necessary to use first-class insulated wires, as it would not be possible to keep such a conduit absolutely dry. Some provision will also have to be made for

passing off gas, which tends to accumulate in the main, and might be set on fire and prove dangerous. It is estimated that the *A* conduit, 10 inches by 15 inches, would cost $15,000 per mile, the *B* conduit, 6 inches by 10 inches, $10,000, and the *C* conduit, 5 inches by 8 inches, $5,000. The *A* size of conduit, which is laid in Chestnut street, Philadelphia, from Third to Broad (equivalent to Fourteenth) streets—(about a mile in length)—is estimated to accommodate 3,000 wires. The *B* size is laid in Tenth, Eleventh and Brown streets, and its capacity is for about 1,200 wires.

By means of the large manholes and separate compartments, the wires in use can be at any time taken out, replaced by others, or inspected and put back, in the shortest time and with no derangement to the pavements and streets. The size of the conduit also enables one to lay a very large number of wires. The prevention of induction would seem to be about equal to that in all systems employing iron-cased ducts, with the additional advantage of interior metallic screws and copper shelves, all well grounded, so that no current in one compartment would be likely to have any influence on those of another.

The conduits were laid down along Chestnut street in October, 1883, and the electric light service has been continuous since the latter part of December of that year, which period included a number of severe storms, of longer or shorter duration.

It has not been ascertained that any interference with the service has been suffered. The weather during the continuance of the exhibition was unusually dry, and, therefore, though the interior of the conduits was dry wherever seen by the examiners, this would not establish the fact of the successful exclusion of moisture by this system under unfavorable circumstances. On this point the undersigned have been compelled to take the testimony of the officers of the company and the statements of the subscribers as to the success of the conduits for the electric light wires.

Few, if any, telegraph or telephone wires were in the conduits, and as it is with these that the defects of any system would be best observed, the examiners have no sufficient data for expressing an opinion.

It is the intention to introduce these insulated telegraph and telephone wires loosely, or without any casing, unless there be a long distance in which no service is ever to be made. Under these circum-

stances the company proposes to use a cable. Otherwise, the wires are to be laid loosely over each other in their various compartments.

A question which is intimately connected with the conduit itself is that relating to the exclusion from it of foreign matter, and especially of water. [The company has suffered from gas in its conduits, and on one occasion an explosion ensued in a manhole near the State House, but this latter caused no serious damage, and it is not thought likely that there are many localities where these conditions of gas waste under the streets are likely to be similar.]*

In the streets of a city where there were great differences of level, any considerable break in the conduits which would permit the influx of a large body of water might (if the latter found free path) do considerable damage. This is an objection applicable to all hollow conduit systems.

Open gratings have been employed to permit the waste gas to dissipate itself, and these gratings have often remained open during both snow and rain storms without introducing moisture into the main conduits, the water escaping by a trap at the bottom of the manhole.

So far as the renters of the light are concerned there is not the least danger of the introduction into their houses of water or gas from this company's conduit, inasmuch as the electrodes are hermetically sealed in a gas pipe which leads them from the handhole.

A telephone wire is laid down in the conduits, leading from the company's central office, in Eleventh street, to Broad and Chestnut streets corner. This was tested in the daytime, when the electric light currents were not passing. The terminal instruments were also out of order. The committee cannot, therefore, say what may be the effect of the electric light current on the telephone lines from this observation.

The following is a description of the figures in the cut:

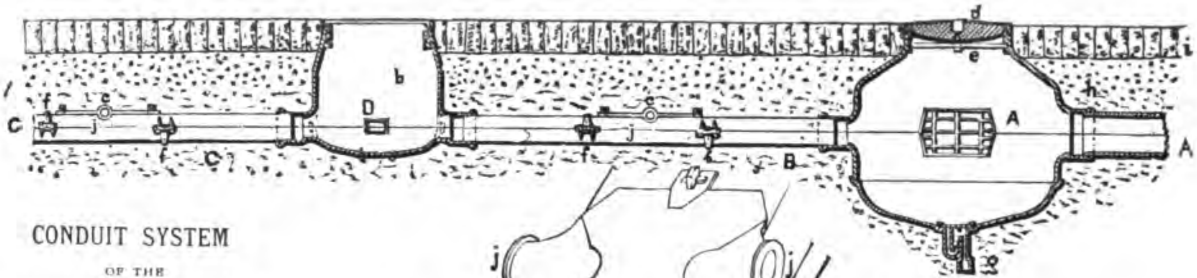
Fig. 1 represents a longitudinal elevation of various sizes of conduit *A*, *B*, *C*, with vertical sections through "manhole," *d*, *e*, *g*, and "flush box," *b*, showing mode of laying and connecting them.

Fig. 2, plan view of same.

Fig. 3, isometrical view of section of *A*, conduit, and hand-hole, *c*, *j*, showing joints of upper and lower sections of conduit, *K*, *K*, partitions and shelves for electric wires, the "static condensing shelves" being shown by dotted lines.

* This report was completed on October 30, 1884.

Fig 1



CONDUIT SYSTEM

OF THE

AMERICAN SECTIONAL
ELECTRIC UNDERGROUND
COMPANY

FOR

UNDERGROUND
ELECTRIC WIRES.

123 S. Eleventh Street,

PHILADELPHIA, PA.

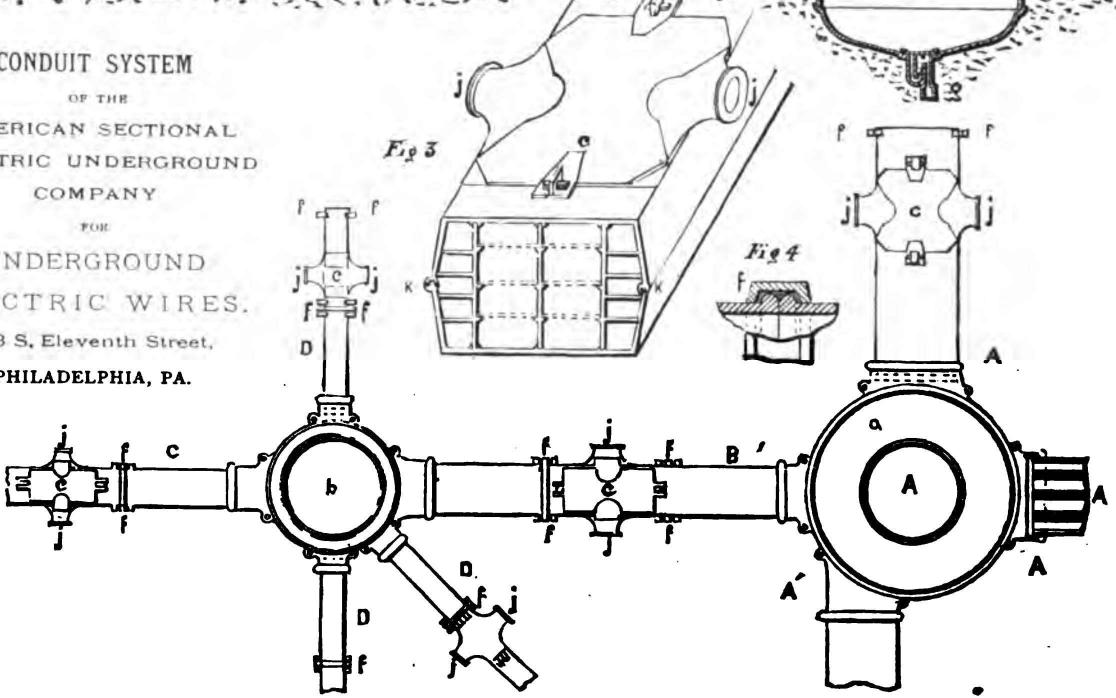


Fig 3

Fig 4

Fig 2

Fig. 4, tranverse section through top of clamp, showing section of ends of conduit and packing at joints.

The letters show similar parts in the different figures, *A* being the largest size conduit yet made, capacity about 3,000 wires. *A′*, showing the conduit opening in manhole when connection is made at one side of manhole or flush-box. *B*, *C* and *D* are consecutively smaller sizes of conduit; *a*, manhole, *b*, flush-box, *c*, handhole, *d*, manhole and flush-box cover made either solid, or perforated for ventilation; *e*, bar with which to fasten cover by aid of bolt and nut; *f*, clamp and keys by which the different sections of the conduit are connected; *g*, trap for drainage of any water which may collect in the manholes and flush-boxes from rain or condensation, and which may be connected with sewer; *h*, street-bed, earth and gravel; *i*, street paving; *j*, hand-hole opening for house connections; *k*, longitudinal joints between upper and lower sections of conduit, to be filled with any suitable packing to exclude moisture, etc.

THE ANDERSON CONDUIT FOR UNDERGROUND WIRES.*

(*"C." of Section's Classification.*)

This conduit is constructed of cellular section and of any suitable material, such as iron, terra cotta or glass. It provides a series of ducts, into which cables or wires of different classes or belonging to different subscribers, may be accommodated. In both sides of the conduit are a series of lateral openings, formed in the process of manufacture of each length of the conduit. These openings give access to the ducts on either side, and are intended for tapping the wires at any desired point. Each side duct, on either side of the conduit, has one of these lateral openings, which are not arranged one over the other, but diagonally and in adverse directions on either side. The object of this arrangement, which appears to be the main feature of the system, is to obviate the weakening of the structure, which would result from having a row of openings one above the other.

No provision is made for manholes, and no arrangements are proposed for obviating the effects of induction, nor for keeping the duct water-tight or free from condensation.

---

* Patent No. 261,979, dated August 1st, 1882.

The description and model were not sufficiently complete to enable the committee to form any opinion of the details, but the provision of a lateral opening to each side duct would have many disadvantages.

THE BROOKS UNDERGROUND CONDUIT.

("A. a." of Section's Classification.)

This conduit consists of wrought iron pipes, supplied with suitable splice-boxes, hand-holes and outlets. These pipes are protected from oxidation by being laid in a wooden trough, into which hot pitch is poured so as to completely envelope the pipe. The wires to be used in this system are covered with cotton and formed into a rope or bundle, which is then covered with a textile weaving. The bundle of wires is then soaked in hot mineral oil and drawn in long lengths into the pipe or conduit. A heavy mineral oil is then forced into the pipe so as to exclude moisture, and for the purpose of maintaining a good insulation.

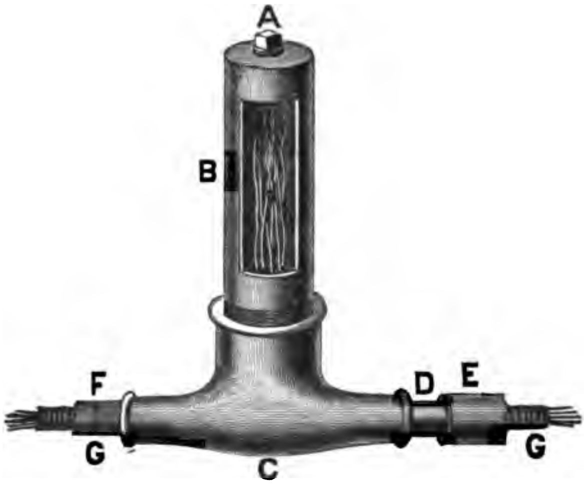


FIG. 1.—Method of making splices.

The patentee estimates the cost of laying a 2½ inch pipe complete, for house-to-house supply, with 40 conductors of No. 16, *B. W. G.* and 360 of No. 20, *B. W. G.*, at twenty dollars per mile per conductor. He states that he can lay such a conduit in one day, from block to block, so that its construction causes but little interference to traffic.

The main point of the system, is the economy of insulation. It is

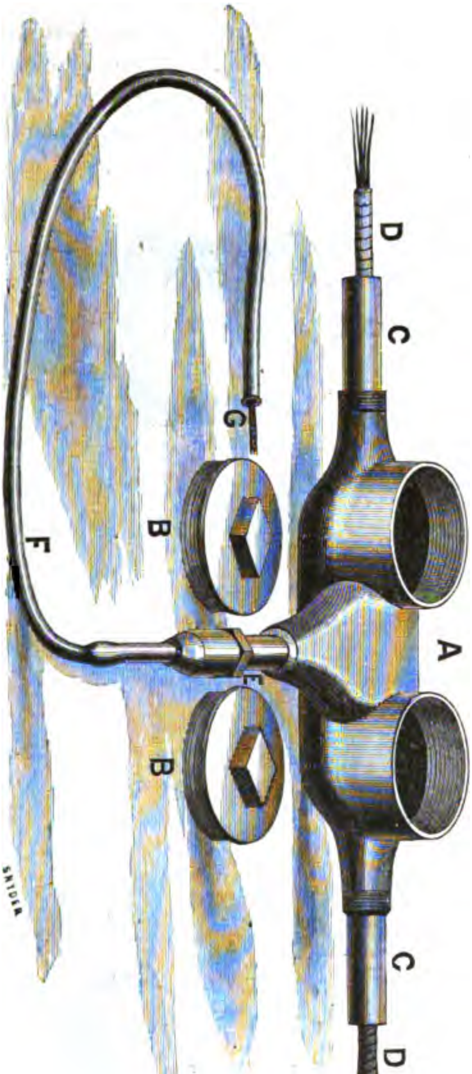


FIG. 2.

proposed to anticipate future requirements by laying down as many wires as may be required for a long time to come, and not to add or withdraw any. It is a system which seems better adapted for trunk or through lines than for house-to-house supply, owing to the difficulty that would be experienced with the overflow of oil at so many points. In towns where there was much difference of level the head of oil would doubtless be a source of great trouble.

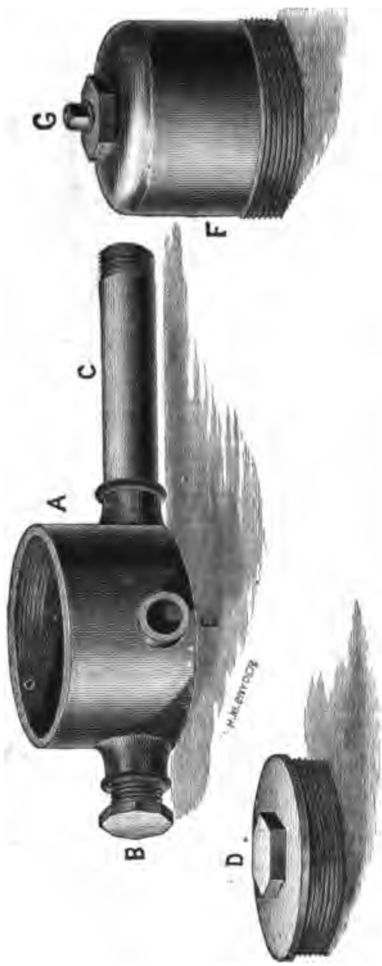


FIG. 3.

Fig. 2 shows the handholes and outlets for taking wires into adjoining buildings. *F*, is a piece of lead pipe, of any desired length, suffi-

cient to reach the first story of the building in which the wires are to be extended or looped. The lead pipe, *F*, is filled with a heavy and viscid oil until it reaches within two feet of the point *G*, where it is spliced to india-rubber or gutta-percha covered wires. The space between the gutta-percha covered wires and the lead tube is filled with plaster of Paris and silicate of soda, which effectually prevents any leakage of the oil.

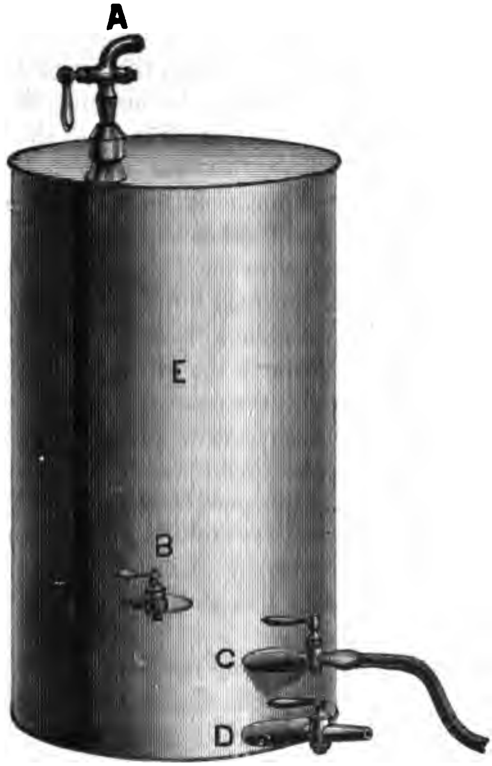


FIG. 4.

Fig. 3 shows a splice-box, hand-hole and outlet on both sides, designed to accommodate 400 wires. *C*, is a two and one-half inch diameter pipe. Reducing sockets can be introduced at *B*, for a smaller pipe and less number of wires. These boxes are introduced at intervals, fastened with plug, *D*, for bringing out the wires. The box is seven inches in diameter inside. When used for splicing the ends of the cable, dome *F* is screwed into the top of the box. *G*, is a plug in the

top of the dome for pouring in oil after the splice is made. On either side of this box is outlet *E*, similar to that shown in Fig. 2.

Fig. 4 shows the tank at the Pennsylvania R. R. Station, Broad Street, Philadelphia, supplying the system with pressure and the oil lost by leakage (which is not perceptible).

As regards the efficacy of the oil, as a means of insulation, Mr. Brooks exhibited to the examiners this experiment: Two wires were attached to the Holtz machine, the extremities being carried into a narrow jar of his insulating oil, in such a manner that while the distance between them was $\frac{1}{4}$ inch in the oil, they were $1\frac{1}{2}$ inches apart at the surface of the oil. On turning the machine, the spark passed above the surface of the oil, and not at all through the oil, even when the distance between the extremities was reduced to $\frac{1}{16}$ inch. A number of experiments were made as to the effect of the Brooks system in reducing induction and other disturbing elements; various circuits having been politely put at the examiners' disposition for this purpose in the Pennsylvania Railroad building.

One of these was a line through a Brooks conduit to the Broad Street Station, and a return through the earth. This line gave a considerable amount of disturbance, the noise being rather deep than loud, and reminding one of visible movement. The voice was carried clear and distinct. A second Brooks circuit was metallic, *i. e.*, the message went and returned by wire, the distance between the station being about $1\frac{1}{4}$ miles. The crackling noise was audible, but not loud or deep. A line to Merion Station and return, by overhead wire (14 miles), worked nearly as well. The crackling was *finer*, *i. e.*, shriller and more continuous, but not so disturbing.

No means were available for testing the amount of interference with each other of the several wires of telegraphic and telephonic circuits in the same tube, worked simultaneously. 2,000 feet of wire is pulled through each length at a time.

THE CONTINENTAL UNDERGROUND CABLE CO.

("*A. b.*" *of the Section's Classification.*)

Description by the Company, edited by the Examiners undersigned.

This company's plans consist of two distinct systems. The first is described in figures 1, 2, 3, 4 and 5, and the second is described in figures 6, 7, 8 and 9. While it is here described more particularly as an electric lighting system, it can as advantageously be applied to wires for other uses of electricity, and is adapted to cross streets, or where one company wishes its own separate conduit. The first-mentioned system being the trunk line system, to accommodate all the different companies in one plant.

In the trunk line system the conduits are constructed with a view of keeping the dampness from penetrating them by either making the walls of asphalt or asphalt blocks (or other anti-moisture material); or by constructing the walls of bricks laid with cement mortar and covering the outside of the wall with asphalt or cement to keep the moisture out, and then keeping them constantly under pressure of dry air.

In order to use a comparatively cheap cable, the conduits are kept dry for the protection and preservation of the cables. And further, they are kept under pressure, and objectionable gases are kept excluded, as dampness or gases will not enter against inside pressure.

At first sight it may be said that there will be considerable cost attending the process of pumping dry air into the conduits, but a conduit of one, two, or three miles in length, may be kept under pressure by a very slight power from a single pump, which may be rented anywhere along the line and connection made to the conduits at a very small yearly cost to the company in conformity with the plan in the patent.

Every electric light company having an engine running to compress the air supplied at the generating station for the tubes containing their own wires, as shown in Fig. 6. The principal object in keeping the wires and conduits under dry air pressure is to prevent the escape of electricity from the wires, or reduce the escape to a minimum. While this principle is adapted to telegraph and telephone wires, it is particularly adapted to underground electric light wires, where very heavy currents are passed; for on long circuits the lights on the farthest end

of the line or circuit burn dimly and are incapable of giving that brilliancy of illumination for which they are designed, unless the intensity of the electric current is greatly increased over the normal, and this is injurious to the lamps near dynamo electric machines and requires a greatly increased expenditure of power used in the generation of the current. By the use of the means employed by this company to retain the full force of the electric current, it is claimed that the distant lamps burn as brilliantly as those near the generators, and all burn with a maximum brilliancy without increasing the intensity of the current over the normal, and with a minimum expenditure of power. The accomplishment of this result depends mainly upon two phenomena, viz., the absorption of the moisture from within the conduits, by chemically dried air (the moisture rendering the air a good conductor), and increasing the pressure or density of the air around the conductors and within the conduit, by mechanical means, the same preventing the free escape of electricity from the wires.

The conduit should be made practically air-tight, with an air compressor at one end adapted to constantly force air into said conduit under pressure, and apparatus to contain an absorbent for the extraction of the moisture from said compressed air, and an escape or pressure valve adapted to remain closed until the desired pressure of air is obtained, and attached to the conduit at its other end or at different places along the conduit, and when the air compressor is put in motion to force a constant current of air under pressure into the main and out through said relief valves, and thereby insure a perfect circulation of chemically dry air under pressure.

The greater the pressure or more dense the atmosphere, and the more free the air is from moisture; the less liability is there for the escape of electricity, and *vice versa*, to follow a natural law which has been demonstrated, the more rarefied the air around an electric wire and the more moisture it contains, the more freely will electricity escape from the wire. By this process every part of the space within the conduit (not occupied by the wires or their covering) will be occupied by compressed or dense dry air. The insulation should be perfect, as there will be no space so small that the compressed air will not instantly penetrate it. In the case of electric light wires, they will be supported within a tube by glass or porcelain supports, as represented in figures 7 and 8, and each wire having an air space surrounding it, the dry compressed air will encircle each wire and insulate it perfectly from all

others. A slight insulating covering as an extra precaution should be used on the electric light wires also.

One of the simplest forms, system No. 1, is shown in Fig. 1. A conduit for one or more cables of wires is arranged on either side of the track to accommodate, combined, 800 wires.

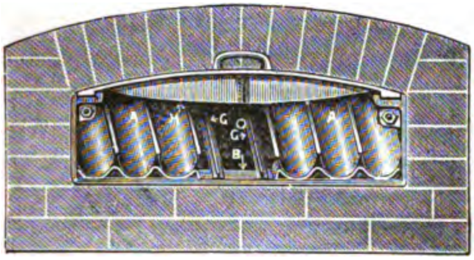


FIG. 1.—Inside measurement, $4\frac{1}{2}$ x 17 inches. Capacity, 800 wires.

That shown in Fig. 1 will probably be sufficient for any one company for many years to come, but where more wires are required the capacity of Fig. 2 should be had, and any single company will probably never require on any street more accommodation for wires than can be had by the conduit shown in Fig. 1, but should a greater capacity be required, the construction shown in Fig. 2 may be used, in

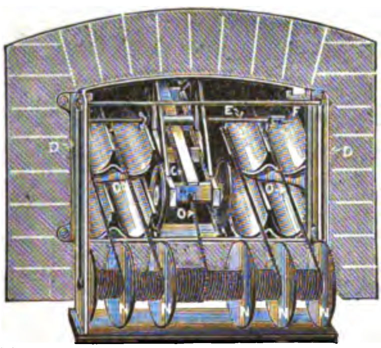


FIG. 2.—Inside measurement, 9 x 17 inches. Capacity, 1,600 wires.

which it is seen that pockets are arranged in a manner similar to that shown in Fig. 1, but two deep. In place of arranging pockets as shown in Fig. 2, they may be arranged as shown in Fig. 3; in which the pockets are arranged in single rows, one above the other, four deep.

Figs. 4 and 5 show the system for laying wires on a larger scale, and which is especially adapted to accommodate a number of separate com-

panies. Each of said figures show the same capacity with but a slight difference in construction, the arms supporting the pockets in Fig. 4 uniting both uprights and a track is furnished to each apartment of six pockets; while in Fig. 5 the arms or brackets do not thus unite, but leave a vertical passage way from top to bottom of the conduit wherein the motor or carriage, running upon the rail of the bottom, causes its adjustable arms to travel when in the act of laying the cords, wires, or cables in the various pockets upon either side of said passage way. For an entire city only one motor and one carriage will be required, or if the process of laying the wires is to be carried on by either the carriage or motor alone, then the one or the other may be dispensed

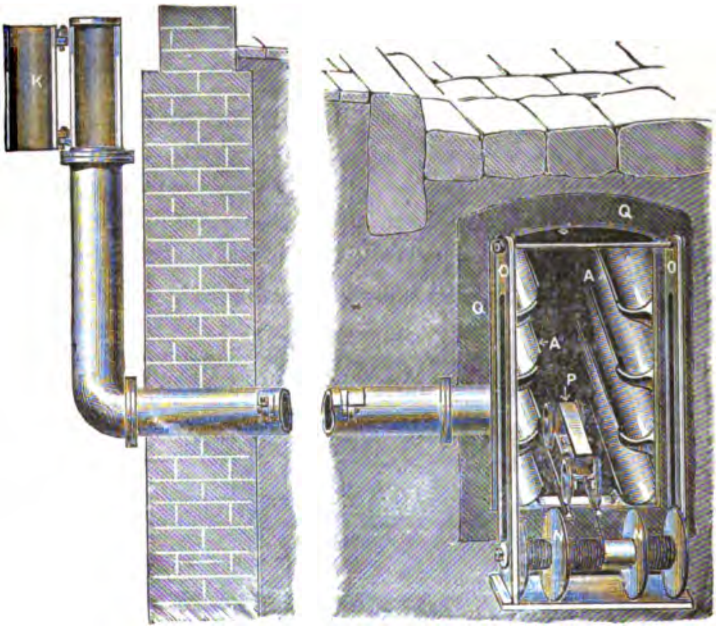


FIG. 3.—Inside measurement, 11 x 18 inches. Capacity, 1,600 wires.

with; the pockets are made semi-cylindrical, three inches wide at the top and an inch and a half deep, or they may be made nearly cylindrical with a slot on the upper or top side running the whole length to admit of the chain or cord being laid in the pocket by the car with which to draw the cables into position. The space for the motor is between five and six inches wide, but reduced to two inches above the railway, and as it extends from the bottom to the top of the conduit, access to the

cables without removing them from their pockets can be had from the top if at any time it should be desired or become necessary.

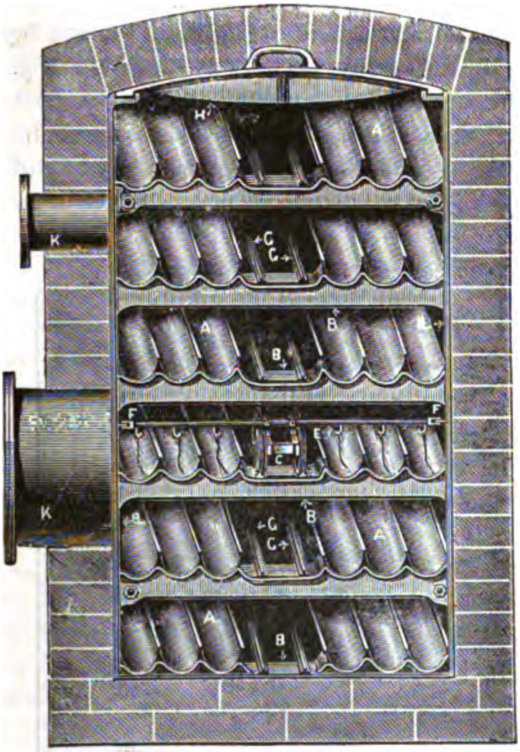


FIG. 4.—Inside measurement, 23 x 27 inches. Capacity, 7,200 wires.

A vertical space of one to two inches is left between the upper and lower pockets to enable the passage of the motor or carriage arm and also to enable the cable to be tapped and the wire taken through an outlet. (See *K*, Fig. 3.)

Service from the conduit to houses may be made by a connection run under the sidewalk and into the cellar, as shown in Fig. 3, conveying wires through said pipe into the houses. The conduit before each house is provided with a plugged branch, which may be opened for connection when required.

Where a number of companies are using the construction shown in Fig. 4, each of said companies can place a suitably arranged lock against admittance to their respective apartments.

Fig. 3 shows an electric motor in the act of drawing a cord or wire cable from a spool supported by an adjustable upright, temporarily placed in a manhole for the purpose; this cable when laid, being adapted to draw the carriage through, which in turn lays a series of cords or cables in the various pockets, as shown in Fig. 2. If it is required that the carriage make two or more trips successively, then the carriage, in being drawn through, may also draw through an additional cable (see Fig. 2), by which said carriage may be returned after laying the first lot of cords or electric cable, and be in readiness for a second supply

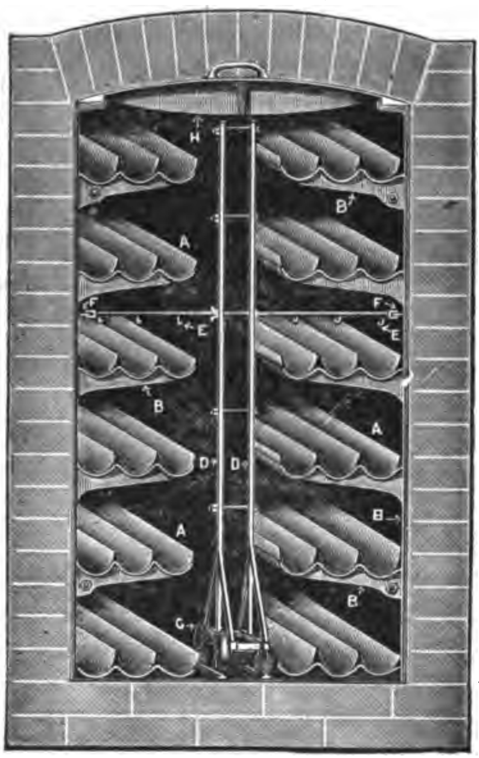


FIG. 5.—Inside measurement, 28 x 27 inches. Capacity, 7,200 wires.

The plan is to place the largest number of wires in the smallest possible space after allowing for space to conveniently get at the wires, lay and relay them, for taking them off to houses and for circulation of dry air, etc.

The walls of the conduit may be built of blocks made from asphalt

compound, by an improved process, whereby it becomes impervious to moisture, and possesses great strength; and the metal uprights, brackets, and pockets, are connected with the earth to carry off induced electric currents to the earth. By this construction the conduit can be built more cheaply than if constructed entirely of iron, and in addition thereto, is not so apt to become electrically charged.

The cylindrical sheet-iron pockets are formed by machinery and in sections of four to six feet long, the ends of which are turned, to receive the supporting brackets, which clamp said pockets end to end. The uprights and brackets are bolted together in a manner as to clamp firmly the ends of the pockets, thus uniting the adjacent sections, and thereby securing a substantially smooth pocket or trough extending from one manhole to the next, the smooth surface overcoming any danger of injuring the cables in the act of drawing them through, and at the same time decreasing the labor. The uprights and pockets with the railway are fitted in the machine shop, and several sections, secured together, are lowered simultaneously to the foundation made for it in the street. These are then closed in and the conduit is complete.

It is estimated that the system just described can be laid with a capacity of 12 to 15 pockets adapted for different companies to occupy separate pockets for their own wires, each pocket having a capacity of 100 to 200 wires (according to the kind of wires or cables are used), for from $8,000 to $10,000 per mile, depending upon the material used in the masonry.

Fig. 6 represents a general view of our electric lighting system in which we have to deal with currents of electricity of high electro-motive force. In such systems in moist weather, or even owing to the dampness of an underground conduit, there is an escape of the current and this materially reduces its tension so as to render the current incapable of producing a light of more than small candle power at a short distance from the generating station. This has been one of the obstacles to placing electric lighting wires under ground where the current was to be conveyed over long distances.

By this system the tension of the current is retained at its maximum, and so far as dampness is concerned the tension is unaffected, thereby conveying currents underground over even longer distances than can be done above ground, under the ordinary variations of the hygrometric state of the atmosphere.

To attain this end the air within the conduit is kept under consider-

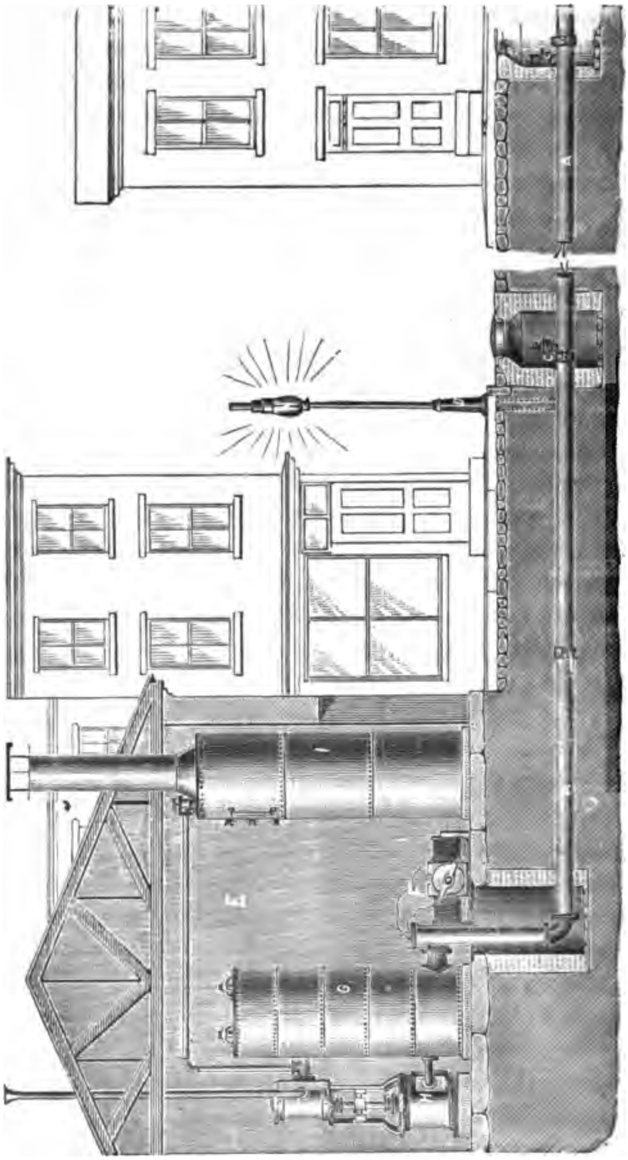


FIG. 6.—Underground Electric Lighting System.

able pressure, and perfectly dry. If there is any appreciable amount of moisture in the atmosphere, the air-pump *H*, forces the air first through a dryer *G*, which absorbs all the moisture, and the chemically dried air passes into the conduit *A*, and when the pressure becomes over a fixed amount, the relief valves *C*, allow the excess of air to pass off, thus keeping the pressure in the conduit uniform. Currents of high tension tend to pass off the conductors, but this tendency

FIG. 7.

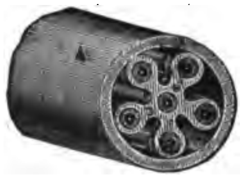


FIG. 8.

decreases as the pressure of the surrounding medium (air) increases, and this effect is greatly increased by the thorough drying of the air in damp weather before passage into the conduit. The drying chemicals may be used over and over again, and the system is adapted to any substantially air-tight conduit. As the pressure is constant there must be an efflux, and should there be a small leak the passage of air will be from inside outward, thus preventing ingress of moist air.

FIG. 9.—Airtight manhole.

Figs. 7 and 8 represent end sections of conduits for electric lighting purposes, in which *B* are the conductors and *A* a metal pipe, the conductors *B* being supported by suitable insulators within said pipe. The conduit *A*, Fig 6, may be continuous with testing doors; in the manholes *B*, or if desired the conduit *A*, may be open on the ends where it enters the manhole; as shown in Fig. 9, in which the door *D*

is made air-tight and covered by an auxiliary cover *F* on the road, the said door *D* being provided with the relief valve *C*. In this construction the manhole is filled with compressed air.

This principle may be applied to general conduits, which may also carry the electric light wires, or instead of supplying the whole conduit with compressed air the electric light wires may be enclosed in leaden or iron tubes, and when laid in the conduit, air may be forced under pressure through said pipes.

Comments by the Examiners.

While the system just described is more particularly intended for electric light wires, and if applied successfully to currents of high tension, it can more easily maintain a good electrical condition for telegraph and telephone wires; and a pipe conduit 3½ inches in diameter can be laid for about $3,000 per mile, and will contain at least 300 wires.

If absolutely dry air could be maintained in this conduit, no doubt it would be attended with many of the advantages claimed for it. But it would be exceedingly difficult to ensure in any conduit of masonry, however carefully built, absolute immunity from moisture, and to keep such a conduit, with its many manholes and outlets under air pressure, would, it is thought, be quite impracticable.

The employment of an electric motor to run a cord or chain through the duct for the purpose of feeding in the wires appears to be a refinement which, to say the least of it, lacks simplicity. Further, the expense of maintaining dry air under pressure by a separate apparatus would be an expensive process both in first outlay and subsequent maintenance.

The employment of dry air, however, in wrought-iron pipes has obvious merits as a cheap and manageable insulator and is well worthy of being developed. The details of the system have not yet been worked out, and the models exhibited showed a new principle, but not so far a practical system.

The COSMOPOLITAN UNDERGROUND TELEGRAPH, TELEPHONE and ELECTRIC LIGHT COMPANY of NEW JERSEY.

Patented May 8, 1883.

(*"A. b." of the Section's Classification.*)

This conduit is constructed of highly glazed terra cotta, in sections two feet in length, with a tap joint on the top and ends, and is bedded on a cast iron or terra cotta base plate.

Its interior is fitted with iron frames, placed at suitable distances apart, which clamp large plates of some suitable insulating material, such as glass. If bare wires be used, they may be drawn directly through the holes, but where insulated wires are employed, the openings should be fitted with short sleeves of porcelain or glass, to prevent the insulation being injured.

Some of the sections are fitted with tubular projections for tapping the wires, wherever required, for house-to-house supply.

Cast iron manholes are placed at suitable intervals.

The slack of the wires is taken up every fifteen feet, and the wires are then clamped.

All the joints are carefully cemented in order to exclude moisture.

It is stated that about one hundred yards of this system has been under trial in Fourth street, Camden, N. J., and that the cost will not exceed one dollar per foot run.

No provision is made for overcoming the effects of induction in telephone wires. After the duct has been laid and filled with wires, no addition or alteration to the wires can be made without laying open the street down to the level of the base of the conduit and remaking all the joints.

THE ELECTRIC TUBE COMPANY.

UNDERGROUND CONDUCTORS.

Statement of the Company, edited by the Examiners undersigned.

The essential form of the conductors exhibited by this company is that of an iron tube containing one or more copper conductors insulated from each other and the enclosing iron tube, and having all remaining spaces in the latter filled with an extremely viscous, almost solid, insulating compound, which becomes fluid at a high temperature. This manufactured product is termed an "Electric Tube." These tubes are manufactured in fixed lengths, generally twenty feet. The conductors project from two inches to three inches beyond the end of the enclosing iron tube, and two lengths of electric tube are joined together by means of copper joints soldered to the projecting conductors and so formed as to allow the expansion of the conductors to take place without injury or danger. Such joints are protected by a cast iron box completely enclosing them and securely fastened to the ends of the tubes enclosing the conductors. This box is then filled with the same compound as the tube and hermetically sealed.

The exhibit of this company showed the great range in the size and number of conductors which the fundamental form of cased conductor permits, and the great flexibility in making circuits of complicated ramifications, which is given by the plan of having joints at frequent intervals; and the methods of making these joints.

To illustrate the range in size, etc., samples of electric tubes were shown containing conductors varying in number and size, from a single round conductor 1·61 inch diameter, of 2,592,100 circular mils. or 2·036 square inches sectional area, in an iron tube 2⅞ inches outside diameter, to 271 wires No. 14 Brown & Sharpe gauge, of 4,100 circular mils. or ·00322 square inch sectional area, in an iron pipe 3¼ inches outside diameter.

To show the manner in which circuits of a complicated character may be made with this form of conductor, circuits such as those used for incandescent lighting on a large scale, having a large number of derived circuits with conductors of widely differing sizes, there was exhibited a portion of an underground circuit such as is used in T. A. Edison's 3-conductor system of incandescent lighting—a system using tubes of which the cross section is shown by Fig. 1.

This exhibit consisted of, first: a "Junction Safety Catch Box." This is a large round box the top of which is flush with the surface of the street; it is provided with a loose outside cover, and a lighter inside cover bolted down to make a water-tight joint with the box; these being removed, disclose the internal electrical connections in a readily accessible position, six inches below the surface of the street. The central portion of the box is occupied by the "Pole Pieces," consisting of as many rings as there are conductors in the system (in this instance three), each ring having as many radial projections as there are tubes entering the box (in this instance six), these projections, which are symmetrically arranged as regards polarity, are all brought to the same level at their extremities and terminate in plane, polished, gold-plated surfaces one inch square, which are arranged equidistant from each other in a circle around the centre of the box. Each of these surfaces has a tapped hole in the centre.

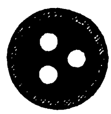


FIG. 1.

In a circle outside the pole pieces, are as many "Safety Catch Joints" as there are conductors entering the box (in this instance 18), these safety catch joints are arranged radially opposite the extremities of the projection of the pole pieces; each consists of a copper or composition piece which has a copper rod soldered into it projecting about eight inches downwards into the body of the box, the upper end of the composition or copper piece terminating in a plane, inch-square, gold-plated surface, the same as those on the pole pieces. These surfaces of the safety catch joints are on the same level as the similar surfaces on the pole pieces, and radially opposite and equidistant from them.

Two feet below the top of the box (that is the surface of the ground) the electric tubes (in this instance 7) enter the box and are rigidly attached to it, the joint being made water-tight. The pole pieces and the safety catch joints are all insulated from each other, but rigidly attached to a support rising in the centre from the bottom of the box.

Flexible copper cables join each conductor, of each tube, with one of

the copper rods which project downwards from the safety catch joints, so that by means of flat safety catches placed across from the safety catch joints to the corresponding projections of the pole pieces, all conductors of like polarity are joined together at this point with a safety catch in each circuit in a readily accessible position, where it can easily be removed or replaced. Such a box equalizes the electromotive force at that point of all lines entering it, or if one of the tubes is a feeder, that is, runs back to the dynamos, the box is a distributing point for several circuits which may or may not be brought together again at some other place.

FIG. 2.

The conductors in the tubes entering this box may be of any size to suit the requirements of the different circuits. The circuits shown entering this box vary from 350,000 circular mils. to 133,000 circular mils. area of conductor, and are arranged to show how they may be laid, bent in different degrees to right or left, joining each other at their extremities; crossing each other and joined together at the crossing; joining other circuits at any point in the length of the latter;

reduced in size at any point of their own lengths, and having derived circuits of any size taken from them at any point of their own lengths; and having all these varied connections of different sized conductors made by means of a comparatively small number of standard patterns of connecting joints, boxes covering the joints, and ball clamps attaching the boxes to the iron tube enclosing the conductors.

The ball clamps, in connection with the boxes, are essential features of all underground conductors of this company's exhibit.

Figs. 2, 3 and 4 illustrate the forms of these parts and the manner in which they are used.

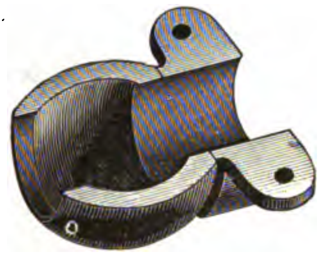


FIG. 3.

Fig. 2 shows the top and bottom halves of a "Coupling Box," a 3-conductor system, and Fig. 3 a "Ball Clamp," whilst Fig. 4 shows the bottom half of the same coupling box with tubes and ball clamps in place and joints connected. The two parts of the ball clamp being bolted together on the tube are thus securely clamped to it, the hemispherical parts come together to make a sphere which fits the spherical socket in the nozzle of the box; the two together thus form a ball and socket joint, allowing free angular movement of the tube in any direction, but preventing longitudinal movement of the box on the tube. The angular movement allowed by the ball and socket is limited to any amount in any direction, by providing a rib inside the box (either separate as in Fig. 11, or forming the inside opening of the

ball-socket of the box, as in Fig. 2) of such a form, that when the extreme amount of angular movement to be allowed in any one direction is obtained, the tube projecting into the box through the ball clamp comes in contact with this rib, thus stopping any further movement in this direction.

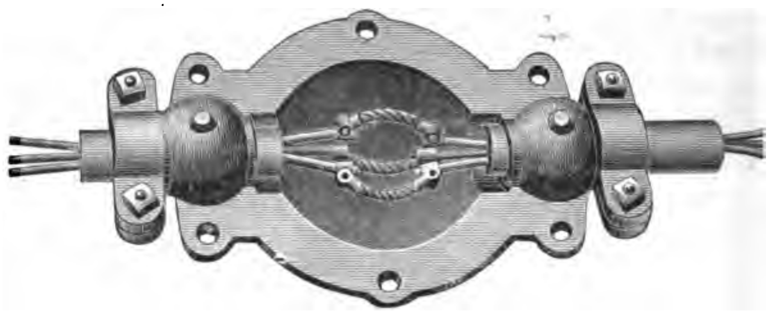


FIG. 4.

The box is made of such size and form, that when the tubes have the extreme angular movement allowed there is still ample space between the joint and the box to prevent the two coming in contact. Rotary movement of the box on the tube is prevented by means of the small lug on the ball of the clamp which loosely fits sidewise, the slot shown in the socket of the box, the slot being sufficiently elongated lengthwise that the lug may have free play in that direction within the limit of angular deivation allowed.

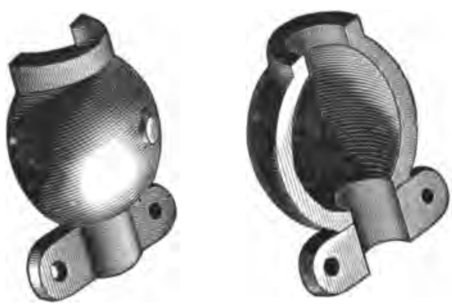


FIG. 5.

The limiting rib inside the box is made to give the angular movement allowed, when the largest size of iron tube that will go into the box is used, but any smaller iron tube may be used in this box (as, for example, in reducing the size of the conductor at this point) by means

of a ball clamp, of the form shown in Fig. 5, with a ball to fit the box, but with a smaller semi-cylindrical groove in each half to fit the smaller iron tube; this clamp has in addition, as shown, a semi-cylindrical ring concentric with the groove cast on the ball of each half; the two, when the two halves are clamped together on the iron pipe, forming a cylinder projecting into the box, of the same outside diameter as the largest iron tube that will go in the box: this projection on the clamp striking against the limiting rib inside the box, limits the angular movement of the smaller iron tube to the same amount as when the largest size of iron tube that will go in the box is used. Therefore the ball clamp and box, as described, whilst making the iron envelope of the conductors mechanically continuous, and preventing rotary movement of the boxes on the tube; allow an angular deviation (in this case 1 in 10) in every direction, at each end of every box, which gives a degree of flexibility to the whole line (in this instance 11½ degrees at each joint) and at the same time renders it impossible that the joint should touch the box, with the extreme amount of angular deviation allowed. The ball clamp, modified as shown in Fig. 5, also permits the use in any box of any tube smaller than the largest that will go in the box, whilst preserving the same limit of angular movement.

FIG. 6.

The flexibility of the whole line thus obtained is necessary for rapid and cheap laying in streets, where, from the number of gas, water and other pipes, sewer-manholes, etc., it is impossible to run tubes in a straight line for any distance.

The joints for 3-conductor tubes consist of pieces of copper wire rope, having cast or brazed on their ends suitably shaped composition sockets, in which are drilled holes to fit the size of copper conductor for which they are intended, and to which they are soldered in laying the line. The joints necessary to obtain the results illustrated by the exhibit are: "Coupling Joints," for connecting two tubes in a straight line (Fig. 6 shows the form of one piece, three such pieces being used for a complete joint); "90° Elbow Joints," for bending 90° to right

or left, and "45° Elbow Joints," for bending 45° to right or left. Fig. 7 shows three forms of pieces, different combinations of which

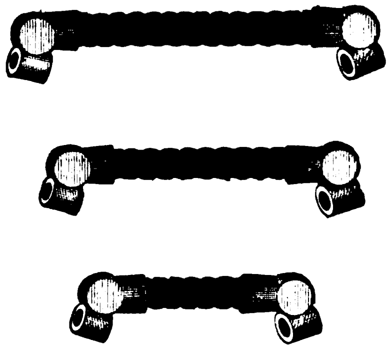


FIG. 7.

will make all kinds of elbow joints. "Branch Joints," by which, to any coupling joint in a line of any sized electric tube, may be attached a branch to one side, or one to each side, of any sizes not larger than the main line. Branches of sizes larger than the main line, being of rare occurrence, are not allowed for in the standard patterns for branches enumerated below, but, when required, may be made by a slight modification of the latter. Fig. 8 shows three forms of pieces, different com-

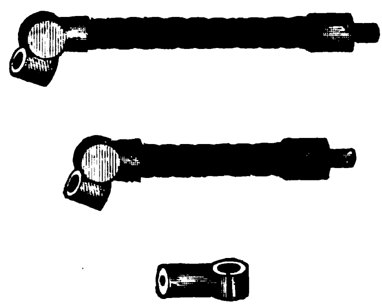


FIG. 8.

binations of which will make, to either or both sides of any coupling joint, branches of all sizes ordinarily required; a few of the largest sized branches require special patterns of modified forms, which are enuumerated below. The form of socket of the coupling joint shown in Fig. 6 gives the copper wire rope of the joint a bowed form when the joint is in place, to allow for the éxpansion of the conductors in each electric tube. The form of the joint when in place is seen in

Fig. 2. Fig. 6 shows that, in addition to the hole which fits the conductor, each coupling joint socket has another hole drilled in it; the male sockets on the ends of the branch joint pieces (see Fig. 8) fit these holes and are soldered in them in attaching a branch joint; the female sockets on the other ends of the branch joint pieces are drilled to fit the conductors of the electric tube used for the branch lines. Fig. 9 shows a coupling joint, with a branch joint attached, in the bottom half of the box used for covering this kind of joint.

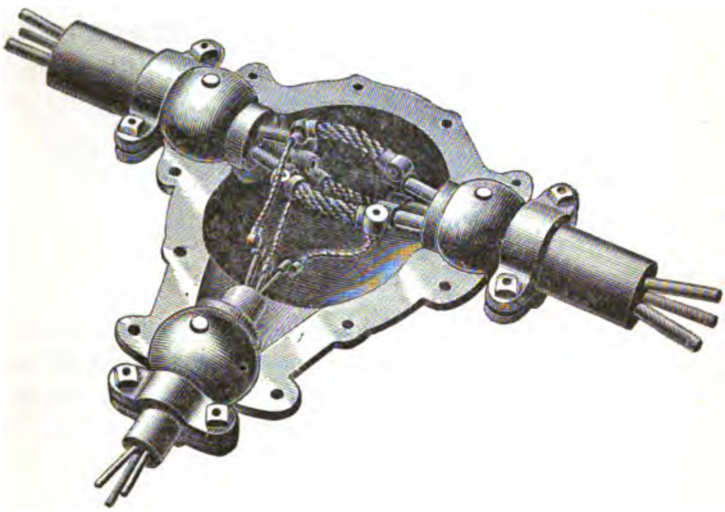


FIG. 9.

The 3-conductor system, so far as it is exhibited, has 21 different sizes of electric tubes, having conductors varying from 500,000 to 27,000 circular miles sectional area. The enclosing iron tubes are of 5 different sizes, varying from $2\frac{3}{8}$ inches to $1\frac{1}{16}$ inches outside diameter. All connections are made with 10 patterns of boxes, 8 patterns of ball clamps, and patterns of 43 pieces for all joints; of the latter, 6 patterns are required for coupling joints for all sizes, 3 of these patterns are also used for elbow joints, which require 15 patterns in addition, making 21 patterns for all varieties of all sizes of coupling and elbow joints. The remaining 22 patterns are for branch joints, and 12 of these will make any combination ordinarily required, the other 10 being for use in cases which rarely occur.

Electric tubes are exhibited cut away to show the internal construction, which consists in wrapping each copper conductor with a layer of

insulating tape, and winding each taped conductor spirally with rope impregnated with insulation; the pitch of this winding is large compared with the diameters of the rope used, so that the windings of the several conductors fit between each other when the conductors are placed together; as many conductors as are to go in one tube, being so placed together, they are bound together by a final spiral winding of rope around them all, and the bundle of conductors thus formed being introduced into an iron tube, the process of manufacture is completed by filling the tube with insulating compound liquid, at high temperature, ready access being afforded the latter throughout the length of the tube, along the spiral paths formed by the rope-winding of the conductors.

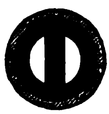


FIG. 10.

Another variety of electric tube is illustrated by an exhibit of a complete set of sample tubes for the 2-conductor system of incandescent lighting, and typical examples of the boxes, ball clamps and joints used with them. The conductors in this system vary from 1,639,890 circular mills, or 1·2879 square inches, sectional area in a tube $3\frac{1}{2}$ inches outside diameter, to 33,015 circular mills, or 0·02593 square inches sectional area in a tube $1\frac{1}{16}$ inches outside diameter, and, there being only two in a tube, economy of space in the latter is secured by making the conductors in the form of segments of circles, as seen in Fig. 10, which shows a cross section of one of these tubes. The joints for these tubes are of cast copper, the allowance at coupling joints for expansion of the conductors being given by making the joints with a U-shaped bend, projecting at right angles to the line of the tube, the section of the joint in the U being flattened to a parallelogram, long in comparison with its width, as is seen in Fig. 11, which shows a coupling joint for this system of tubes, with bottom half of coupling box. Holes are bored in all joints of the same form as the conductors for which they are intended, and to which they are soldered in laying. Boxes are exhibited with short tubes entering them, and joints connecting the latter, showing the forms assumed by different sizes and varieties of coupling elbow and branch, joints and

boxes. Fig. 12 shows one variety of one size of 90° elbow joint, with bottom half of elbow box.

In both the 3 and 2 conductor systems, boxes and joints are shown for use in in-door lines of these tubes. The flexibility of the line which is required for underground work, and which is given by the

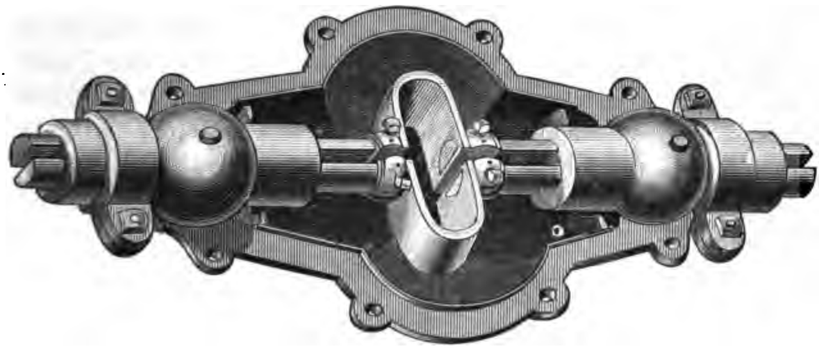


FIG. 11.

ball and socket connection of clamps and boxes, is not necessary in in-door lines; the boxes may therefore be smaller on this account, and also on account of the absence of the ball clamps, the mechanical con-

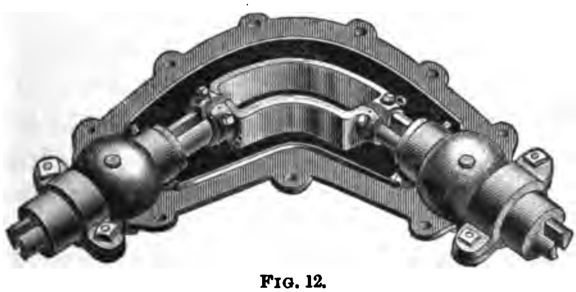


FIG. 12.

tinuity of the iron envelop of the conductors being secured in small space by means of a ring which is screwed on the threaded end of the iron pipe and fits in a groove cast in the neck of the box (which neck fits the iron tube); this box is made in halves, which are bolted together over the joint, the end of the tube, and the ring screwed on the latter.

Underground arc light circuits were illustrated by two exhibits showing the character of the tubes and joints and the method of taking

loops to lamps. One showed tubes with two round conductors for a complete circuit in one tube.

Fig. 13 shows this exhibit, and the method of making the joint so that, the branch tube being led off to a lamp or lamps, the two conductors of the branch form a loop of the main line. The second exhibit shows the case of a circuit completed by a line on another street. In this exhibit the main line tubes entering the box have only one conductor each, the conductor of each tube being joined to one of two conductors of the third tube, forming a loop from the main line of a single conductor. The joints are of wire rope of the same character as the joints for the 3-conductor system. Ball clamps are used to connect tubes with boxes.

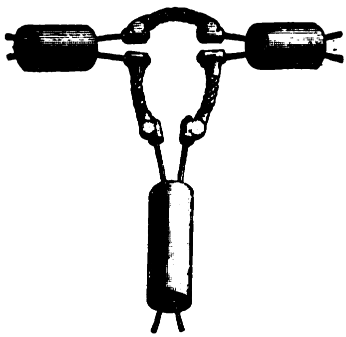


FIG. 13.

A distinct variety of electric tube is that designed for telegraphic and telephonic use. In this case, the conductors being large in number and small in size, instead of the spiral rope winding round each conductor, the insulating covering is continuous, and a rope winding is only used round the outside of a bundle of such wires. The wires are laid together regularly, on the basis of a hexagonal cross section for the bundle, and at each end are threaded through wooden screens which have holes drilled in them, in the same relative positions as the wires occupy in the tube. At one end of each tube, before being threaded through the screens, the wires are woven together so as to change the relative positions of the wires. This operation of weaving is simple and systematic, and the same for all tubes with the same number of wires, and is arranged on such a basis, that in conjunction with a systematic rotation of consecutive tubes, alternately to right and left, in the process of laying, it produces, in a series of long period, method-

ical changes in the relative positions of the wires in consecutive tubes, for the purpose of neutralizing the effects of induction. In making the joints of these tubes, wires threaded through corresponding holes in the screens are bent outwards and placed together in the same notch of a series of notched wooden slats, one for each layer of wires in the joint, which are built up one above the other, as the process of making the joint proceeds. When all the wires are so bent out, the ends are clipped off, leaving about 1 inch projecting through the wall of notched slats; the insulation is then slipped off the ends and each pair joined by a small sleeve, which is soldered to them to make the joint. In general, the joints of half the wires are made on one side and half on the other side of the box. Grooves are provided in the boxes into which they fit the wooden screens through which the wires are threaded, and the series of wooden slats built up in making the joint, holding these securely in place. By this method of making the joints, every joint of every wire, at intervals of 20 feet, is brought into a position in which it is readily accessible for purposes of testing, making connections, etc., without interfering with any other wire, so that at any such joint, loops or single service wires may be attached to any or all of the wires in the line. A line of this character, containing 37 wires was exhibited, with several consecutive boxes and joints to show the system of weaving wires in conjunction with alternate rotation of tubes. Such a line is adapted more particularly to telegraphic uses. Another box was exhibited, constructed with especial reference to the needs of telephone service, for which, in addition to trunk lines between stations, a number of wires are required for services in each block, and only run from the station to that block, thus giving a line between two stations a size decreasing gradually from each station to some point between them. The box exhibited, which showed a joint in a line of 217 wires, had a low turret rising from its upper half, the top of this turret was closed by a loose outside cover and an inside cover bolted down, and making a tight joint with the box by means of a rubber gasket; the whole being made water-tight by filling the space between the two covers, with the insulating compound. In every such box, along the face of a block, all those wires which are intended for use as services in that block, are bent upwards instead of outwards, in making the joint so that the joints of all such wires project upwards into the turret and are held in position by a wooden frame shown, whilst the the joints of all other wires are made out to the sides at a lower level;

this arrangement allows the box to be filled with insulating compound, covering all the wires and all joints, except the joints of those wires intended for use in that block, which latter joints project up above the surface of the compound, and on removing the cover of the turret are all immediately acccessible at every box along the block, for attachment of services, to any or all of them. Tapped holes are provided around the turret on the level of the joints of service wires, into which service tubes may be screwed, if electric tubes are used, or brass nipples to which are soldered the lead covering, if lead covered wires are used for service connections.

This company also exhibits specimens of lead covered wires of small sizes, and a specimen of flexible heavy conductor for indoor use, with large currents consisting of copper wire rope, taped, wound and lead covered. They also exhibit specimens of insulating tape, in rolls of 125 feet, continuous length, varying in width from 6 inches to ¼ inch, and jars of the insulating compound used in the tubes and boxes.

Comments by the Examiners Undersigned.

This system may be summed up as belonging to division "A a" of the Section's arrangement, or that in which the electrodes are permanently sealed. When any portion of an electrode is destroyed a new one is not introduced, but a new length of pipe is substituted, containing the necessary number of wires and attached at its extremities. The details are very fully given, and with the cuts render it unnecessary to repeat them. With a large stock of lengths and boxes and with trained workmen, the work of laying the conductors only a few inchee below the surface of the streets would be comparatively rapid. While in the tentative stage of underground service this does not present the same amount of convenience as a system where wires may be introduced and removed at will; and presents the objection common to all "section" systems that the conducting capacity of the whole line is that of the most imperfect of splices made every twenty feet, yet it answers the demands upon it much better than those systems which require expensive and tedious derangements of the street in order to accomplish repairs. The seat of an accident to one of the wires of this system is located from the central office, on and between known streets. The manhole is opened and the safety catches first of all examined. The managers assert that the place of the break

can then be so accurately located that the length containing it (usually about twenty feet) may be at once removed and replaced by another.

The telephone and telegraph, and the light and power wires are not enclosed in the same tube. The insulating material with which the boxes are filled is still flexible at 32° F., but brittle at 0° F.

The method of laying and tapping for private dwellings would seem to afford complete protection against lightning. The three-wire system which has been grafted upon the Edison conduit system effects a saving of 62 per cent. on that required for the two conductor system, in the copper necessary for conductors.

The light and power system are not adapted for use by various companies, independently, though the telephone and telegraph conduits might be so applied.

The details of this system have been so perfectly elaborated, that in view of the fact that no complete description of it has been heretofore made public, the undersigned deemed the above full report desirable.

THE NATIONAL UNDERGROUND ELECTRIC COMPANY OF NEW JERSEY.

("C." of the Section's Classification.)

This conduit consists of a number of metal tubes imbedded in a kind of insulating pitch, formed in a suitable trough. At the corner of each street there is a water-tight man-hole for hauling in or out wires as required. Provision is also made for tapping wires for house-to-house supply. This forms the subject of a separate patent. It is proposed to place telephone, telegraph and electric light wires in different tubes, so that they shall not interfere with one another. The metallic lining of the ducts, it is claimed, will pass off readily any induced currents which may be generated. The moisture or damp can be kept out by forcing dry air through one or more of the tubes or conduits from a fixed plane along the line.

The Company state that the cost of the conduit per mile will be $8,300. A mile of conduit has been laid under Market street, Philadelphia. The committee were unable to examine its condition, as it contains no wires at present.

(No electrotypes were furnished by the company to accompany this report.)

HENDLEY'S CONDUIT FOR UNDERGROUND LINES.

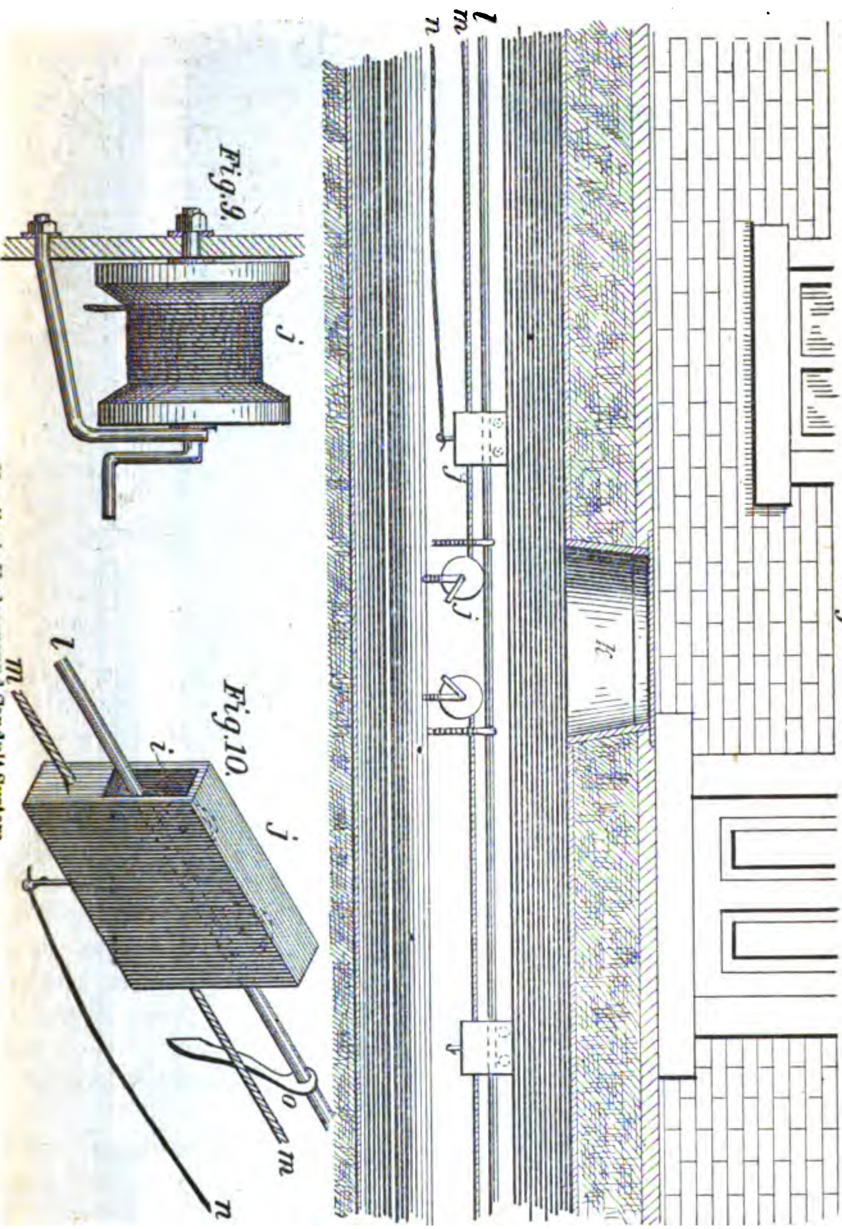
"A. b." of the Section's Classification.)

Description of Inventor, edited by the Examiners undersigned.

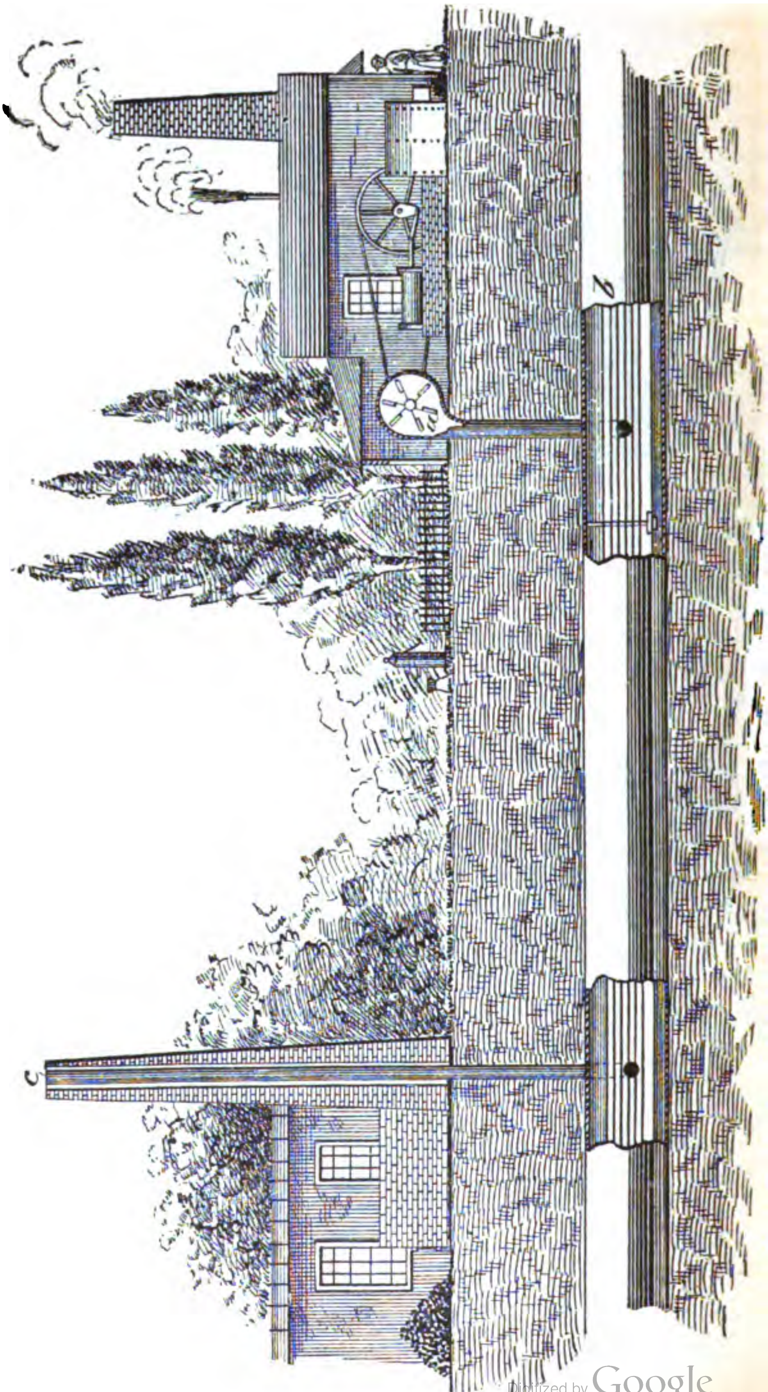
This system consists of a semi-cylindrical trough or conduit for the reception of the conductors, with a suitable cover of any desired configuration, angular shaped being preferred, as by its removal, when necessary, the wires and their supports are more thoroughly exposed. Below the trough and integral therewith, is a drain-pipe of suitable diameter, for carrying off all moisture that may find its way into the conduit by condensation, exudation or leakage. A narrow slot extending throughout the length of the trough opens therefrom into the drain-pipe, the curved sides of the former rendering it almost impossible for any heavy particles of moisture to remain therein, this slot serves also to sustain the bolts which pass through the shoe to which the standard of the wire supports are secured, thus rendering it easy to place the supports at such intervals as may be desired, along the conduit. This structure, with the supporting arms is really "a telegraph pole underground." Modifications of these slotted arms have been suggested, which it is thought would, in practice, make this feature thoroughly effective.

Testing chambers are placed at such suitable points along the line as may be necessary, and in these, provision is made to test, tighten and otherwise manipulate the wires. A full description of this feature of the system cannot be fully set forth herein. At one side of the conduit brackets are secured, and from these rods extend, over which travelers having suitable pulleys in their interior which move on the rods, pass and carry the wires from man-hole to man-hole, cords are attached to each side of a traveler, and pass thence to reels secured near the surface of the earth, these man-holes can be placed at frequent intervals along the line, by securing wires to a suitable clamp at the bottom of the traveler, and they may be run in at any point simply by reeling in the cord.

Pipes for inducing currents of air are led into chimney stacks the heat of which is made available for that purpose, or they may pass into the open upper air, and currents of hot or cold dry air may be forced into the conduit by means of fan blowers, both devices may be used, though either separately would be effective for carrying off all



Hendley's Underground Conduit System.



Hendley's Underground Conduit System.

the lighter particles of moisture, and thereby keeping the conduit thoroughly dry and at a uniform temperature all the year round, and thus rendering, it is thought, a thorough insulation of the conductors unnecessary. Provision may be made by this system for a future increase in the number of conductors to be employed, without having to tear up the streets, so that when once the system is built it remains a permanent and available plant, adapted not only to present but to future use.

Comments by Examiners.

This conduit consists of a semi-cylindrical trough of iron, terra cotta, or preferably, of glass, fitted with an angular-shaped cover. At the bottom of the conduit there is a pipe connected to it by a slot, for the purposes of drainage, and for fixing a standard with recessed and insulated arms for carrying the wires.

Man-holes are provided at suitable points, and also small pipes for house to house supply.

Provision is made for either ventilating the conduit by induced currents of air, or of forcing hot or cold air through it in order to expel all moisture. No provision is made for induction in telephone wires. The standards carrying the wires are secured to the conduit by one bolt each, and it would seem difficult, without continual inspection, to keep them in position.

NOTE.—Neither the inventor nor any one representing him could be found to answer the questions of members of the Section as to his method of running in wires, etc., and no estimate of cost was furnished.

MAGNER'S UNDERGROUND CONDUIT.

Patented June 10, 1884.

("*A. b.*" *of the Section's Classification.*)

This system consists of a conduit constructed of cast iron, terra cotta, etc., having a longitudinal slot *A′* at its top, for the introduction of wires or cables. This slot is beveled and made tight by bolts and clamps bearing on the inside of the conduit (See Fig. 5.) The joint is further secured by suitable packing.

The wires or cables are supported on insulated rollers, which revolve freely on a series of horizontal shafts, suitably supported and arranged one over the other. These rollers may be formed in one piece, or may consist of a number of independent rollers separated by washers. The distance apart of the rollers both horizontally and vertically, is such as to prevent contact between the wires or cables, when strained up.

The Inventor claims that his system provides a conduit applicable to all descriptions of wire or cable; which is easy of access for the insertion or removal of any wire or cable, and in which the wires are kept taut.

The Inventor did not submit any plan for manholes, or any arrangement for providing house-to-house supply, nor does he claim any method of obviating the efforts of induction. He proposes to lay down well insulated wires, as the conduit would be necessarily more or less damp.

After the conduit has been laid and filled with wire, any alteration to the system would require that the street should be opened from end to end.

FIG. 2.

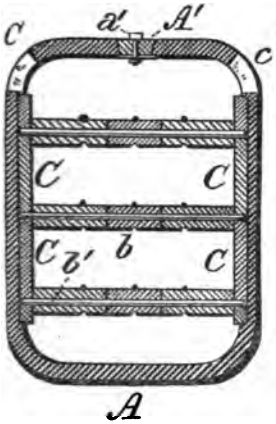


FIG. 1.

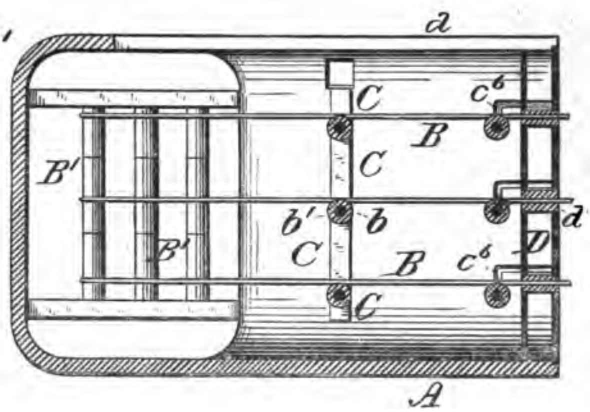


FIG. 5.

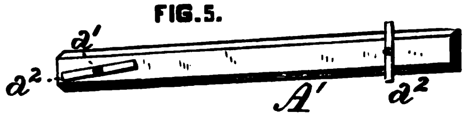


FIG. 6.

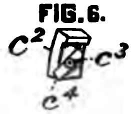


FIG. 4.

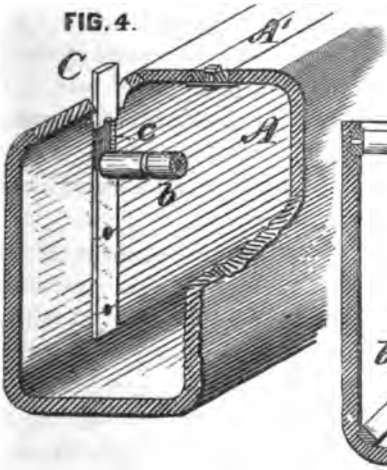


FIG. 3.

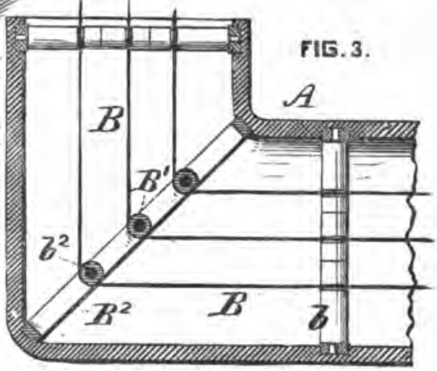
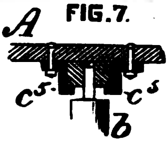


FIG. 7.



PHILADELPHIA AND SEABOARD TELEGRAPH AND CABLE COMPANY.

(CALLED ALSO PENNOCK'S.)

(*"A. a." of the Section's Classification.*)

Description of Pennock's Underground Conduit for Telegraph and Telephone Wires.

The material used in constructing this conduit, consists of hemlock wood, copper wire, various compounds and insulations, the nature of which the inventor did not disclose.

The wood is exposed to a solution for several hours, at the temperature of boiling water. The composition being easily distributed through the mass of soft wood, incrusts the cells with a compound which makes the wood absolutely moisture and decay proof. The carpenters now take the wood (which has become dry and hard) and make a hollow box—the core of the conduit—which is filled in with insulated telephone wires, arranged according to a plan not disclosed. When the core is filled, insulating material is again poured upon the wires, filling in the interstices, making a dry solid mass. The top is now cemented on. The finished core now receives a second coating of the waterproof compound. (Fig. 1 shows the completed core.) Around this core are now built the receptacles for the insulated telegraph conductors (as shown in Fig. 2.) There are two inches of insulating impermeable compound between the telephone and telegraph circuits, 6 inches between all sides, ½ inch all around.

The finished core is now set in the outer shell of the conduit, which is also made of the prepared wood, 1 inch thick. A moistening compound is now run in around the core and the top covered with a plank of the same prepared wood, pressing into the compound, making two inches of solid impermeable matter between the core and the casing, three inches between the core and the earth, 5 inches between the telephone and the earth. The sections are all prepared at the factory before being taken on the ground. They are run into sleeves every 20 feet; 20 loops are run out on each side of the sleeve and covered with a water-proof cap, so that the wires are at all times accessible. The wires are connected through the sleeve with a patent, hard paper, double connector.

The electric light conduit is made in a similar manner, but the wires

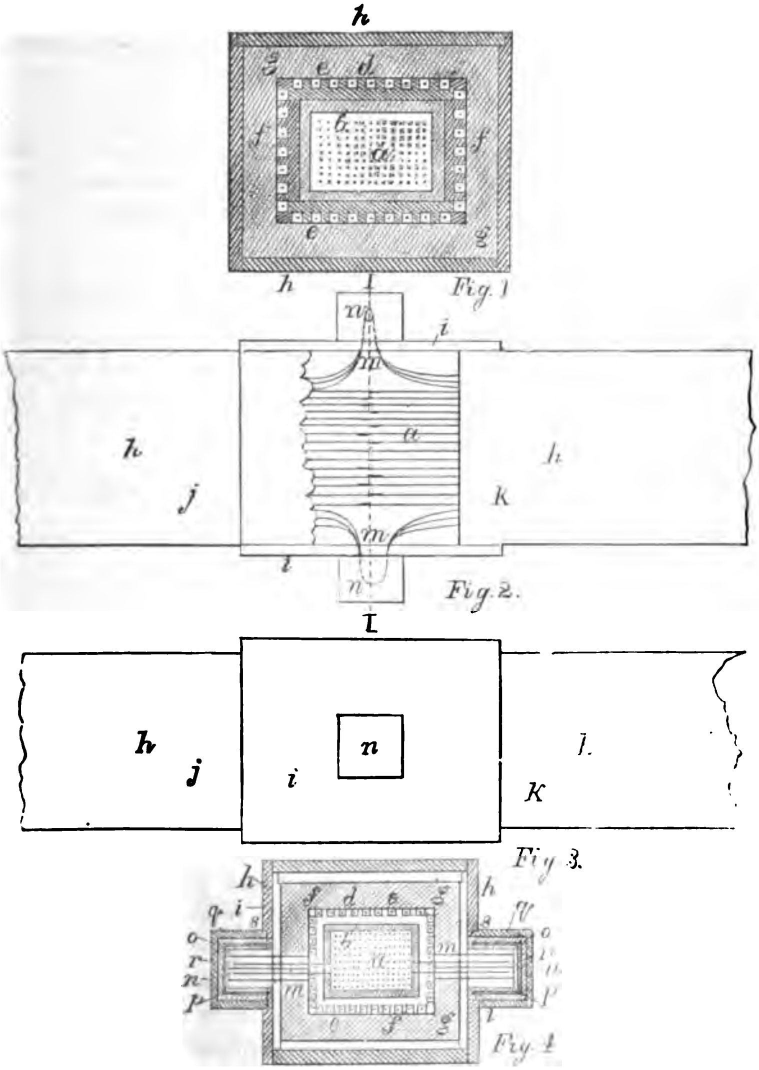


Fig. 1

Fig. 2.

Fig. 3.

Fig. 4

are widely separated, and different materials are used in insulating and fire water-proofing.

The advantages claimed for this system are: (1.) It is fire-proof; (2.) It is water-proof, it will not decay; (3.) It is a perfect insulator; (4.) No leakage between telephone and telegraph wires; (5.) The arrangement of the conductors in the lanes to divert induction, etc.; (6.) The wires will not corrode; (7.) The wires cannot break, no pulling of cables through tubes, no abrading, no strain; (8.) Insulated wires can be tapped and conveyed into each dwelling without disturbing the main conduit; (9.) It is cheaper than a pole line.

Price per mile for 100 Telephone wires, delivered on ground........	$2,500
Price per mile for 1000 Telephone wires, delivered on ground........	$9,750
Price per mile for 100 Telegraph wires, delivered on ground........	$2,750
Price per mile for 1000 Telegraph wires, delivered on ground........	$12,750

Comments by the Examiners.

The whole success of this sytem would depend on the nature of the insulating material and the chemical preparation of the wood, etc. Without trial, over an extended period of time, it would not be possible to test this conduit for endurance and the other points claimed by the inventor.

THE UNION ELECTRIC UNDERGROUND COMPANY OF CHICAGO.

(" *A. a.*" *of the Section's Classification.*)

This conduit consists of a tube ten inches in diameter, of kalamine (a mixture of lead and tin) which is said to resist the chemical action to which all underground conduits are subjected—on each side of this main, smaller tubes of the same metal, two inches in diameter. The large tube is designed to accommodate the main wires and the small tubes those which run short distances, and at regular intervals there are joints by which house-to-house connection can be made. Instead of the wires being covered with an insulating coat, from which they cannot be withdrawn, they run through a tiny pipe, a little smaller than the familiar maccaroni tube, and this pipe is manufactured independently of the copper wire. When this pipe has been tested, the copper wire is forced into it by an ingenious machine. Should the copper wire at any time need repairing the same machine withdraws it from the well-fitting covering and then replaces it.

The inventor claims that this tiny tube is the best insulator known. It is made of vulcanized rubber, three sixteenths of an inch being its thickness, and one-sixteenth of an inch being the diameter of the opening. The rubber is covered with a thick electric deposition of copper. The deposition surrounds the tube and is said to prevent induction by carrying the surplus electricity into the ground.

By the tubè system each wire can be removed without the others, with which it is bunched, being disturbed in any way. The electric light wire which, on account of the great insulation, can be handled with perfect safety when the strongest current of electricity is running on it, costs less than $500 a mile, or half the usual cost, and takes up about half the space that an electric light wire usually occupies.

The inventor claims that by the use of his special insulation he can run all descriptions of wire in one tube.

The conduit can be laid for $8,000 a mile. The main tube will hold 1,700 wires, and the side tubes 50 each.

The insulation was found to be very brittle—and it would be difficult to bend it out of the manholes and tapping tubes without injury. The wires must be necessarily very expensive—not only to manufacture, but to force into their insulated tubes afterwards.

WOODWARD'S CURB CONDUIT.—SYSTEM B.

("A. b." of the Section's Classification.)

Company's Description Edited by the Undersigned Examiners.

In the accompanying engraving, Fig. 1, is a perspective view of the combined curbstone and conduit, showing the wires in position; in the second figure the wires and cover are removed; Fig. 3 is a vertical section taken at a street corner; and Figs. 5 and 6 are plan views at street corners, the former being an inlet corner and the latter the usual rounded corner; Fig. 4 is a horizontal section illustrating the method of securing together the conduit sections in order to permit expansion and contraction. The hollow curb conduit sections, *A*, made of cast iron or other suitable material, are formed with vertical sides above the street pavement to form the curb, and those portions sunk in the ground are widened out at the bottom to guard against displacement and provide ample space. The cover, *J*, is about flush with the sidewalk. Between the cover and the top of the ledges is placed a water-tight packing. The wires are supported by a series of vertical

racks, *E*, fixed at suitable intervals apart. The lower ends of the racks enter sockets in the bottom of the conduit, while their upper ends pass through holes in cross stays, *D*, the extremities of which rest in brackets on the sides. The ends of the conduit section are flanged and bolted together, packing being inserted between them.

When it is necessary to provide for longitudinal expansion and contraction of the several sections, they are made with overlapping ends, and are secured by bolts passing through slots in one of the flanges. Packing is placed between the joints. The wires are inserted from the open top of the conduit and rest in the teeth of the racks; after they are in position the cover is bolted down. When it is desired to conduct one or more wires into a building, small lateral pipes, *L*, are connected to the side of the conduit. With this construction the wires are always easily accessible and the tearing up of the pavement in order to reach particular points is obviated. The two-plan views show clearly the methods of rounding corners. When the conduit crosses the street where the curb ends, those wires which are above the line of the depressed part are directed downward (Fig. 3), and kept in place by means of transverse studs, *N*.

The advantages claimed for this system are: That it is easier and cheaper to place the wires in the curb than to tear up the streets and put them in an underground conduit.

That owing to the curb conduit widening and deeping from the level of the paved street it gives ample room for holding any number of wires.

That to introduce into a house any telegraph, telephone or electric light wires, by merely removing a few bricks from his pavement, the connection is made direct with the curb conduit, instead of excavating many feet of earth in the pavement and the street by the underground conduit.

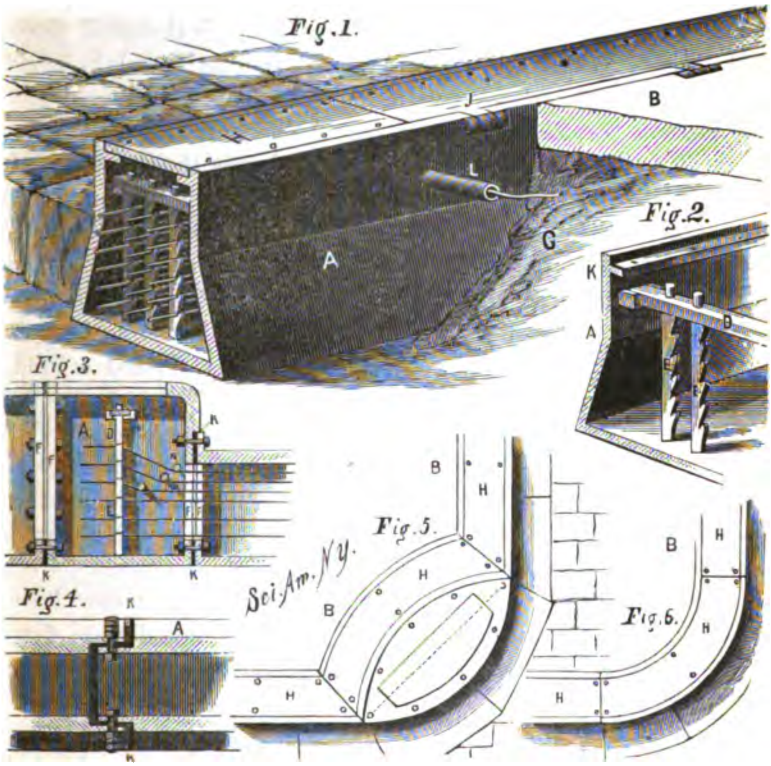
That it is always accessible.

If anything happens to a wire, or a new one is to be introduced, one can always get to it in the curb conduit, and during the snow and ice of winter when the authorities of cities will not allow the streets to be opened, the curb conduit is as accessible as in the warm months of summer.

Comments by the Examiners.

In this system no provision is made for keeping the conduit free from moisture, so that a first-class insulation is required for the wires or cables used. Further, no method is proposed for obviating the efforts of induction in telephone circuits.

To obtain the advantages claimed for it, a conduit must be run on both sides of the street in order to give house-to-house supply.



It would further appear that a long line of iron plate along the sidewalk would be dangerous to foot passengers in frosty weather, and would interfere with present arrangement of gas lamps and the existing sub-pavement and street cellars.

No estimate of cost was given. The system would necessarily be an expensive one.

THE DELANY CABLE

FOR ELECTRIC LIGHTS, TELEGRAPHS, TELEPHONES AND ALL ELECTRICAL CONDUCTORS.

Description of the Inventor Edited by the Examiners.

("C." of the Section's Classification.)

This cable may comprise any number of conductors desired, and of any size required. When a single conductor is used, a bare or cotton-covered wire, insulated in any of the usual ways, is threaded through small disks or buttons of vitreous material, such as porcelain or glass, so that the conductor throughout its entire length is covered by the incombustible buttons which are about half an inch in length and one-eighth of an inch in thickness. The conductor thus surrounded is passed through a compound of insulating material and through a lead press machine which encloses the whole in a lead covering or pipe, so that, when finished, the cable or conductor is first enclosed in a braided covering saturated with an insulating compound, then surrounded by the incombustible disks or buttons, again covered with an insulating compound which is forced in hot as the lead pipe is formed around it. The latter filling occupies all the interstices and space between the conductor and the vitreous buttons and between the buttons and the pipe, thus leaving no air spaces and thereby preventing condensation of moisture. The incombustible material separating the conductor from the pipe, renders the transmission of the most powerful currents absolutely safe, since under no circumstances can the conductor come in electrical contact with the pipe. Should the conductor become heated the soluble insulating compound would be united more firmly, closing up any cracks that might have occurred from low temperature or contraction.

When a series of conductors are used they are all threaded through separate holes in the same disk or button, and thus mechanically separated from each other and from the pipe in which they are enclosed.

This cable is practically indestructible, as its durability is only limited to that of the enclosing pipe, which may be of lead or iron. When lead is used the cable may be constructed in lengths of one-quarter or half a mile without splicing, and coiled on a reel, the vitreous disks admitting of flexing to any extent necessary.

The conductors cannot become crossed, nor can they be grounded so long as the enclosing pipe remains intact. As the lead pipe is formed around the cable in a molten state, there is no seam, weld or joint throughout the entire length in each section.

All danger from fire in buildings is obviated. Rats cannot destroy the insulation and the cable may be laid in chimneys, ventilation or heating flues, or placed in the walls like gas or water pipes, with perfect security against interruption or damage, or the necessity for tearing out the walls for repairs of any kind.

Three tests of this cable were made at the International Electrical Exhibition, for the purpose of ascertaining the effect of powerful currents on the insulation. These tests were made under the direction of Capt. de Wolski, Chairman of the Committee on Underground Conductors. The first consisted of placing a piece of cable about five feet in length so as to short-circuit the Hochhausen electro-plating dynamo-machine. Ths conduetor, a single one, insulated as described in the beginning, was No. 4 Birmingham gauge copper wire. The dynamo-machine had an electro-motive force of two and one-half volts. A current of 600 amperes was passed through the cable for 20 minutes. The conductor was made red hot, but the insulation was uninjured, the melting of the filling-in compound being the only result of the experiment.

The second test was similar to the first, with this difference in the current—800 amperes were sent through the cable for 20 minutes. The wire became so hot that the vitreous disks surrounding it melted the lead covering, leaving the insulation uninjured.

The third test was with the conductor inclosed in an iron instead of lead covering. When sufficient current could not be passed through the conductor to cause any effect other than the melting of the filling compound and charring of the braided covering on the wire. The conductor was perfectly secure in its insulated separation from the pipe and consequently free from all danger.

This single conductor, insulated and inclosed as described, ready for use in the ground or elsewhere, can be furnished for 22 cents per foot. Six separate conductors of No. 16 copper wire, for telegraph or telephone use, and covered in a like manner, will cost the same amount.

The foregoing report is respectfully submitted by

F. D. DE WOLSKI (*Chairman*),
PERSIFOR FRAZER.
LUTHER L. CHENEY.
Examiners of Section XVIII.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS

REPORTS OF THE EXAMINERS

—OF—

SECTION XIX.

(SECTION IV, CLASS I, OF THE CATALOGUE.)

ELECTRIC TELEGRAPHS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

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CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XIX.—TELEGRAPHIC SYSTEMS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XIX, on Telegraphic Systems.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XIX (on Telegraphic Systems), respectfully present the following report.

FRANK L. POPE (*Ch'n*),
Examiners of Section XIX.

PHILADELPHIA, *December*, 1884.

REPORT ON TELEGRAPHS.

(SECTION XIX.)

I. TELEGRAPHIC SYSTEMS.

The different methods which have been from time to time devised for increasing the working capacity of a single telegraph wire by enabling it to simultaneously transmit two or more communications in the same or opposite directions are technically termed duplex, quadruplex and multiplex systems. Four telegraphic systems of this general character are exhibited: the synchronous-multiplex telegraphs of T. A. Edison and P. B. Delany, the well known quadruplex of Edison, and the Morse-harmonic duplex of Elisha Gray. Each of these systems except the first is in commercial use in the United States. That of Mr. Delany is of quite recent introduction, and for this reason as well as for its remarkable ingenuity, both in conception and execution, deserves special attention.

The possibility of employing a single conductor for the simultaneous transmission of two or more sets of telegraphic signals appears to have originated with Moses G. Farmer, of Boston, Massachusetts, about the year 1852.* Mr. Farmer attached to each end of the line a rapidly revolving commutator or distributor. The two distributors when caused to revolve synchronously and in unison, served to bring the line successively and simultaneously into connection with a corresponding series of short branches at each terminus, in each of which branches ordinary telegraphic apparatus was inserted and operated in the usual manner. Thus the current through each pair of corresponding branches at either station, while apparently continuous, actually consisted of intermittent but rapidly recurring synchronous pulsations. Mr. Farmer successfully experimented upon a small scale, upon the wires of the municipal telegraphic lines of Boston, in 1852. Nothing of permanent value, however, resulted from the experiments at that date, the difficulty of maintaining the absolute synchronism required for operating for any considerable length of time being apparently insuperable. Many subsequent inventors have sought to render this method practically useful; among others Mr. Edison, whose apparatus is exhibited and will be hereinafter referred to. The apparatus of Mr.

* United States Patent, No. 9,634, March 29, 1853.

Delany, now for the first time publicly shown in operation, appears to realize to the utmost the possibilities inherent in this method. The methods of multiple transmission which thus far have found the widest practical application, of which Edison's quadruplex system is a well known example, are based upon a wholly different principle, that of differential or balanced currents or magnetic forces, which may properly be considered an outgrowth of the invention of Dr. Wilhelm Gintl, of Austria, in 1853.* Still another system is based upon the discovery of Elisha Gray † that two or more sets of harmonic vibrations may be set up at the same time in a continuous electric current, and separated from each other at the receiving station. Upon this discovery Mr. Gray has based a system of harmonic multiple telegraphy. The present exhibition therefore affords practical examples of each one of the three fundamental principles upon one of which every multiple telegraph has hitherto been founded, viz: the *synchronous*, the *differential* and the *harmonic*.

THE DELANY SYNCHRONOUS-MULTIPLE SYSTEM.

This system is founded upon an invention of Paul Lacour, of Denmark, made prior to 1878, and termed the "phonic wheel."‡ The phonic wheel is employed for regulating and rendering approximately synchronous the revolutions of the distributors at opposite ends of the line. The two principal difficulties which Mr. Delany has been obliged to overcome in reducing this system to practice are, *first*, the maintenance of the necessary synchronism: and *second*, the utilization in the formation of signals, of exceedingly short pulsations of electricity.

Speaking in general terms, it may be stated that Mr. Delany has, in our opinion absolutely overcome the first of these difficulties, by the happy conception of providing for an automatic mutual interchange of correcting pulsations at frequent intervals between the separate instruments, in case there exists any tendency towards deviation from the normal speed, the latter being approximately controlled by the vibrations of a tuning fork, acting electro-magnetically upon the phonic wheel. It has been conclusively demonstrated that synchronism

* Prescott. Electricity and Electrical Telegraphy, p. 769.

† Journal of American Electrical Society, 1875. Prescott's Electricity, p. 876.

‡ United States Patent, No. 203,423, May 7, 1878.

may be maintained continuously for days, between two instruments at opposite terminals of a telegraph line, without a variation exceeding the six hundredth part of a second.

The effective rate of speed with which the apparatus can be operated, or more properly, the actual transmitting capacity of a given conductor equipped with this apparatus, depends, *first*, upon the rapidity with which successive impulses can be made to traverse a line, while preserving to each impulse a degree of strength sufficient to produce the movement of the armature of a relay at the receiving station, and *second*, upon the mechanism by which these pulsations may be made available in the production of arbitrary signals representing letters and words.

The rapidity with which the successive electrical pulsations can be produced at the distant end of a given telegraphic line, is inversely in proportion to the resistance and electro-static capacity per unit of length of the insulated conductor and inversely as the square of its length.* Other things being equal, the rapidity is greatly augmented by forming a connection directly between the line and the earth at each end of the line between each two pulsations. This operation is provided for in Mr. Delany's apparatus. The employment of pole-changing or double-current keys and polarized receiving instruments (a suggestion understood to be due to Mr. E. A. Calahan, who has been associated with Mr. Delany in the development of the invention), enables short and rapid pulsations to be utilized to the fullest extent in the formation of the signals of the conventional telegraphic code. For a detailed description of the apparatus we would refer to a recently published paper by Professor E. J. Houston.†

The actual performance of the apparatus, during the tests made by the committee, over 200 miles of line (from Philadelphia to Jersey City and return) was eminently satisfactory. The rate of rotation of the distributors was stated by the exhibitor to be 170 revolutions per minute, the same as that of the instruments in daily commercial use between Boston and Providence, a distance of about fifty miles. At this rate of speed the duration of each contact was 0·0021 seconds. With the apparatus arranged for six distinct communications, either all in the same direction, or partly in one direction and partly in the other, we

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* Sir William Thomson. Proceedings of Royal Society, May 24, 1855.
† "Journal of the Franklin Institute," January, 1884.

ascertained by actual trial that communications could be received with distinctness upon the ordinary Morse sounder at a rate of from thirty to forty words per minute. With the apparatus arranged for twelve communications a rate of twenty words per minute was attained with equal facility. The application of the system, however, is not limited to the simultaneous transmission of twelve messages, for by the use of a type-printer especially designed for the purpose (specimens of which are exhibited with the other apparatus) as many as seventy-two independent circuits may be actuated. This is necessarily effected at a less rate of speed, although it is quite sufficient to enable each of the separate users of the line to transmit during six hours at least 100 dispatches of the average length, a speed which may be increased proportionately when desired, by placing at the disposal of the user one thirty-sixth or one eighteenth instead of one seventy-second of the entire capacity of the line.

EDISON'S SYNCHRONOUS-MULTIPLE TELEGRAPH.

This system is exhibited in Mr. Edison's collection of apparatus illustrating his inventions, and was devised by him in 1876.* It consists of two heavy tuning forks, one of which is placed at each end of the line, and kept in vibration by an electro-magnet and automatic circuit breaker or rheotome. By meams of adjustable sliding weights upon the forks; their vibrations may be made synchronous. Suitable contact springs are provided, which are moved by the vibrations of the forks, and by means of these the main wire connecting the two stations is simultaneously transferred from one to another of a succession of short branches at each terminal station, each branch containing an ordinary telegraphic apparatus. This apparatus is of historical interest, as marking an important step in the progress of invention intermediate between the original plan of Mr. Farmer to which we have already referred and the perfected apparatus of Mr. Delany, Mr. Edison we believe being the first to make use of tuning forks for controlling the synchronous transfer of the main line from one branch to another at the terminals. The apparatus of Mr. Edison has met with no practical application, a circumstance which is doubtless due among other things, to the lack of any automatic means of correcting the synchronism of the forks.

‡ U. S. Patent, No. 200,993, March 5, 1878.

EDISON'S QUADRUPLEX TELEGRAPH.

The original form of this well-known apparatus is shown in Mr. Edison's collection. With some modifications it is now in extensive use by the Western Union Telegraph Company throughout the United States. To convey some idea of the usefulness and commercial value of this apparatus it is sufficient to say that it has increased the telegraphic facilities of the Western Union Company to an extent equivalent to the addition of 50,000 miles of wire. It is also employed to a considerable extent in Europe. The principle of differential or balanced circuits upon which it is constructed and operated is so well-known as to require no detailed description in this report.

GRAY'S HARMONIC DUPLEX.

This ingenious and effective system enables the capacity of an ordinary telegraph line to be doubled or trebled by an addition of a small amount of supplementary apparatus. The principle upon which it acts is as follows: If we take the case of an ordinary telegraph line, operated according to what is generally known as American Morse system, in which the line is traversed by a normally closed circuit passing through a number of stations, both way and terminal, each of which is provided with a circuit-breaking key for transmitting signals and an electro-magnet for receiving them. The alternate opening and closing of any one of the keys in the circuit produces corresponding signals upon all the electro-magnets. According to Mr. Gray's invention one or more additional sets of signals are superposed upon the continuous current, by means of vibrating harmonic transmitters, these produce rapidly recurring series of rhythmical vibrations, by slightly increasing and decreasing the strength of the current in rapid alternation. These vibrations are responded to by one or more electro-magnets, each having a tuned reed armature. Thus it will be seen that a second and a third series of signals may each be transmitted by a key controlling a particular set of vibrations, and received upon correspondingly tuned armatures, without in the least affecting the ordinary Morse instruments. Inasmuch, however, as the line is entirely severed and interrupted by the operation of the keys as ordinarily used, it is necessary to bridge over the gap formed by the open key, in such a manner that the harmonic vibrations will not be interrupted. This is done by connecting the terminals of the key through an artificial resistance, which is sufficiently great not to permit enough current to

pass to operate the ordinary telegraph instruments, although the harmonic vibrations continue to pass through it freely especially, when an electro-static condenser is provided in addition to the resistance. This system is well adapted for the railway service, inasmuch as the harmonic communication may at a small expense be applied to the ordinary Morse circuit employed by all railroads for regulating the movements of trains, it may be used as a through communication for the general business of the officers of the railroad, or if desired, for ordinary commercial telegraph business, without incurring the expense of an additional wire, or the inconveniences necessarily entailed by any alteration in the established method of operation.

EDISON'S AUTOMATIC-CHEMICAL ROMAN LETTER TELEGRAPH.

This system, which is also exhibited by Mr. Edison, is an improvement upon the well-known typo-telegraph of Bonnelli. Like the Bonnelli system, five independent line wires are employed, and the record is made in plain Roman letters upon chemically prepared paper. The receiving instrument is in fact essentially the same as that of Bonnelli, except that the paper is carried forward by a small electro-motor instead of by clock-work. The method of transmission, however, is a novel one, and possesses some points worthy of notice. The communications to be transmitted are first prepared by means of a punching machine operated by a piano key-board. Each key, when depressed, selects from a group of twenty-five cylindrical punches arranged in a solid square, the necessary punches to form the corresponding outline of a Roman letter, and this group of selected punches is, by appropriate mechanism, driven through a strip of paper, thus forming the required letter from lines of circular perforations suitably arranged, like the perforations of a stencil pattern. The strip containing the message formed of these perforated characters is then caused to pass underneath a series of five styluses, placed side by side in a transverse row, to each of which styluses one of the five line wires are attached. As each perforation passes beneath the point of its corresponding stylus, the latter drops through it, and closes the circuit upon a metallic roller underneath, thus producing a mark upon the chemical paper at the receiving instrument in the same relative position upon the tape that the corresponding perforation is in the pattern strip.

This apparatus was shown in actual operation upon a short line and its performance appeared to be excellent. The extraordinary rapidity

with which messages can be transmitted and recorded upon the tape, far exceeding that attainable by any possible system of mechanical printing, would seem to indicate that this apparatus may yet prove to be of great value for market quotation and commercial news telegraph lines. These lines being generally of no great length, the increased number of wires required would not constitute a very serious objection.

EDISON AUTOMATIC-CHEMICAL TELEGRAPH.

This apparatus is an improvement upon the well-known chemical telegraph of Alexander Bain. Aside from numerous improvements in mechanical construction of the apparatus, the leading feature of novelty is in the organization of the perforating apparatus, which is provided with two sets of punches whereby the conventional alphabet may be formed by means of a double set of circular perforations arranged in two rows. Means are provided whereby upon a depression of a lettered key upon a piano key-board, the appropriate punches which form the corresponding character of the telegraph alphabet are selected and forced through the paper, thus forming a complete character by a single depression of the proper key. The perforation can be effected with great rapidity, a speed of fifty or sixty words per minute having frequently been attained by expert operators. The strip thus prepared is passed through a circuit-closing transmitter and the record is made in the usual manner upon chemical paper. A speed of transmission of 1,000 words per minute has been attained by this apparatus upon a wire between New York and Philadelphia, 100 miles in length. This system was at one time in commercial use to a considerable extent in this country, but has been abandoned, for reasons probably due more to peculiarities in the commercial requirements of American telegraphy than to any inherent difficulties in the operation of the mechanism itself. The automatic method of transmission, although full of promise, has in almost every instance failed to realize the expectations of its advocates, as a substitute for the ordinary process of manual transmission. This difficulty, whatever it may be, is inherent in the principle itself and is not properly chargeable to defects in the operation of the apparatus.

EDISON'S AUTOGRAPHIC TELEGRAPH.

This apparatus is included as a portion of Mr. Edison's exhibit. It was not set up in such manner that its construction or mode of opera-

tion could be examined, and we are therefore unable to report upon it. It may perhaps be proper to say, that the autographic system for the transmission of communications in fac-simile, would seem to afford one of the most promising fields for the labors of future improvers of the telegraph. It is apparently in this direction, if any, that we must look for the future solution of the problem of cheap telegraphy. It will be readily understood that if an efficient system were invented by which the original message, as written by the sender, could be placed in a machine and a fac-simile of it instantly produced by the action of electricity at a distant station, and this by automatic machinery without the intervention of human hands, the actual cost of performing the service would be but the merest trifle. Yet there is apparently no obstacle in the way of obtaining this result which we may not hope to see overcome, sooner or later, by the genius and perseverence of our inventors.

II.—Telegraphic Apparatus.

THE WESTERN ELECTRIC COMPANY.

This company exhibits a complete assortment of telegraphic instruments and apparatus of all kinds, manufactured in their workshops at Chicago, New York and Boston. Among the apparatus worthy of special commendation we mention the following:

REGISTER.

This register embodies several novel features which greatly add to its utility and convenience of manipulation. The mechanism is mounted upon a circular base in such form that the clock-work and paper reel may be covered by a movable glass shade, and thus completely protected from dust, while at the same time it presents a very ornamental and attractive appearance. The paper tape containing the record is made to pass out through an opening in the base beneath the glass cover. This instrument is constructed either for embossing the paper, or for marking with ink, as may be desired. A self-starting apparatus, of novel and effective design, is supplied, by which the clock-work is automatically started and stopped at the commencement and termination of a message without the assistance of the operator. This feature especially adapts this register for the fire-alarm, police or messenger service, as well as for private telegraph lines worked upon the Morse system. This instrument is worthy of the highest praise,

not only for the elegance of its design and finish, but for its effectiveness, durability and perfect adaptation to the purposes for which it is intended.

It is interesting to compare this latest model of the telegraphic register with one of the first pair of original instruments which is exhibited in the historical department. This pair of instruments was constructed, in 1843, under the personal supervision of Alfred Vail, who was intimately associated with Professor Morse, both in the invention and in the introduction of the American telegraph, a considerable part of the mechanical work having been done by his own hands. Vail invented the combination of mechanism for registering, consisting of the electro-magnet, marking point and grooved roller, an apparatus so simple and effective that it has never yet been superseded. There appears also to be little doubt that to Vail is also justly due the credit of devising the conventional alphabet of dots and lines, which has become the universal telegraph language of the world.

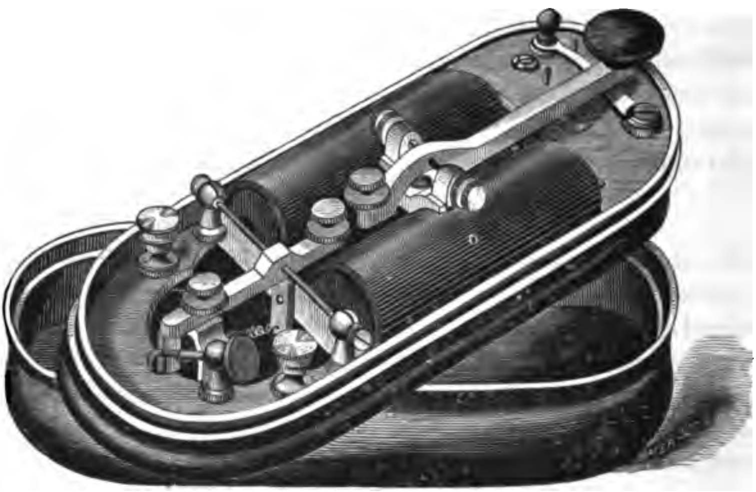


FIG. 1.

The close resemblance between the original and the modern instruments, except in certain matters of comparatively unimportant detail, becomes strikingly apparent upon a critical examination. The electro-magnet, lever, retracting spring, steel marking point, grooved roller and clock-work for moving the paper, are almost identical. The driving weight of the original system has been replaced by a coiled

spring; the self-starting device by another of more effective construction, and the relative position of the parts has been somewhat changed, but the instrument nevertheless remains, to all intents and purposes, the same as when it first came from the hands of Vail, more than 40 years ago.

POCKET RELAY.

This is a portable instrument, much used by line repairers and telegraphic operators in the military service (Fig. 1). It is enclosed in an oval hard-rubber case, about four inches by two, and weighs but a few ounces. Notwithstanding the small size of this case, it contains a complete telegraphic apparatus, consisting of a key and sounder, for sending and receiving messages. The electro-magnet is large enough to be thoroughly efficient; the key is of sufficient size to be convenient of manipulation, and the sound of the receiving instrument is remarkably loud and clear. It is a matter of some interest to contrast this exceedingly minute and well-finished apparatus with that used on Morse's first line, in 1844, and at that time supposed to be indispensable, consisting of a receiving instrument, of which the electro-magnet alone weighed 180 pounds!

THE LEWIS LEGLESS STEEL LEVER KEY.

This is a well-designed and well-finished transmitting key (Fig. 2).

FIG. 2.

It has a steel lever, combining lightness with strength, together with a certain desirable degree of elasticity, and having its terminal binding posts upon the top of the base, so that it may be set up without the necessity of boring holes through the table, a provision which is often found to be very convenient in practice.

STANDARD MORSE SOUNDER.

This sounder is provided with an extra thumb-nut on the adjusting bar, to maintain the spring at a constant tension. This is a minor feature, of much utility, which has been generally neglected by all manufacturers of such apparatus, and we therefore think it deserving of special mention.

GRAY'S PATENT CUT-OUT, LIGHTNING ARRESTER AND GROUND SWITCH.

This is a most convenient and effective device for connecting the instruments in a telegraph office with the main line and disconnecting them at pleasure (Fig. 3). The apparatus is so arranged that this can

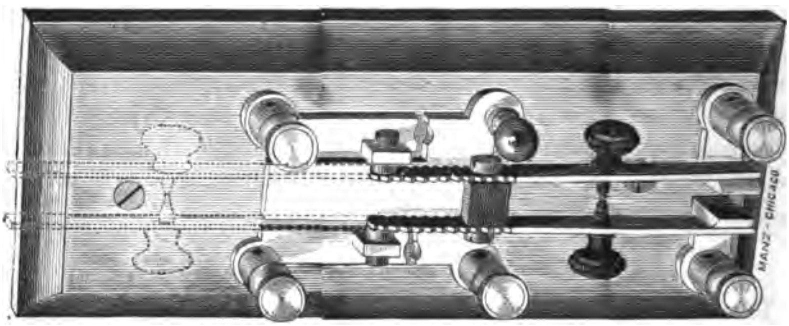


FIG. 3.

be done in an instant, and without causing any interruption of the line. It is obviously far less liable to get out of order than the wedge-switch and divided plug usually employed for the same purpose, and is certainly no less convenient in its manipulation.

PRIVATE LINE INSTRUMENT.

This apparatus comprises a full-sized and well-finished Morse key and sounder (Fig. 4), mounted upon a metallic base and provided with binding-screws, ready for immediate connection with the line. It is adapted to work a line of any length up to 20 or 30 miles. This instrument is no less remarkable for its efficiency than for its low cost. It contains all the essential apparatus for a telegraph office except the battery, and is sold for $4.

The Western Electric Company also exhibit a complete assortment of modern telegraphic apparatus and fixtures, which although possess-

ing no novelty of design deserve particular mention for their excellence of finish and careful adaptation for use. All the instruments shown by this Company are handsomely nickel-plated and present a very attractive appearance.

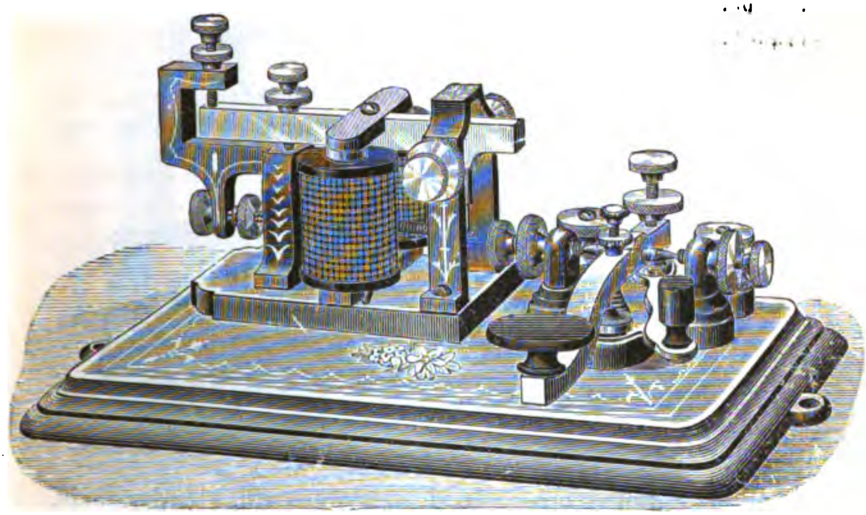


FIG. 4.

THE STEVENS TOP CONTACT KEY.

This is an improved construction of the transmitting key of the Morse telegraph, invented by E. G. Stevens, of Cleveland, Ohio, and exhibited by the Standard Electrical Works of Cincinnati, Ohio. The contact point is at the extreme rear end of the lever, and when raised by the depression of the knob of the key to form a signal, impinges upon a flexible arched arm. The object of this arrangement is to avoid the concussion produced by the operation of the ordinary key in striking downwards upon a solid anvil which is rigidly secured to the table. Such an improvement has been regarded by many practical operators as a desideratum; as with many persons the concussion of the lever is exceedingly fatiguing to the hand, when working for many hours continuously. This is thought by many to be one of the principle causes of the disease known as "operators paralysis." This modification has been introduced without giving rise to any additional complication or other objection, and we commend it as an improvement of value, for the reasons mentioned.

PARTICK AND CARTER.

This firm exhibit a complete assortment of telegraphic apparatus adapted for all ordinary uses, all of which are well constructed and handsomely designed. Among the instruments presenting special points of excellence we would mention the following:

RUBBER CASE POCKET RELAY.

This is a small and compact portable instrument for line repairers and military operators,

FIG. 5.

and is enclosed in an oblong hard rubber case with circular ends. It is about four inches in length including the case, and weighs but a few ounces. The transmitting key is of unusually large size in proportion to the remainder of the apparatus, and this, as well as the sounding mechanism, is very ingeniously arranged in a compact form so that although very little space is occupied, the operation of the mechanism is remarkably effective.

STANDARD AMERICAN REGISTER.

This is an accurately constructed and well finished form of embossing register.

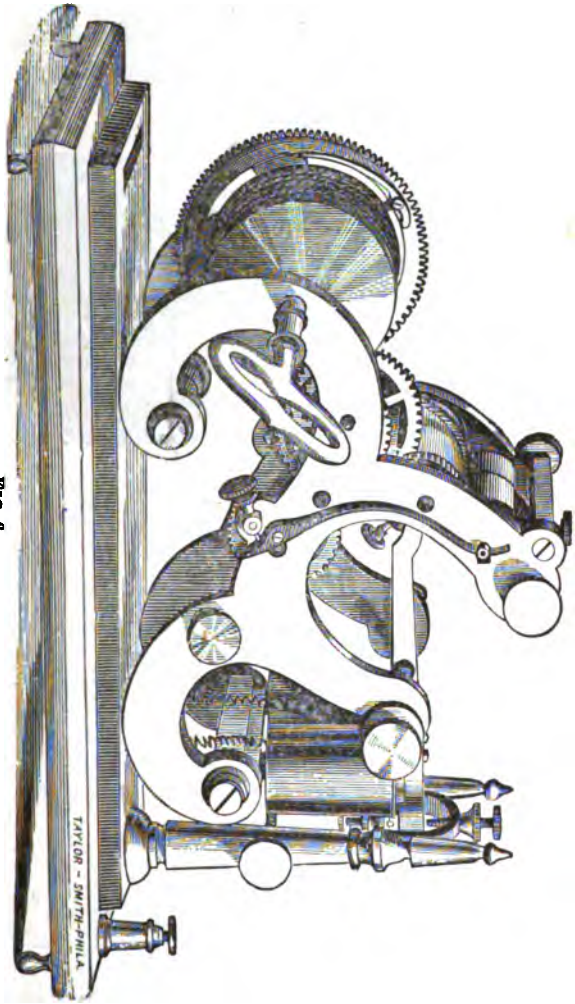
A special feature is the arched bridge upon which the limiting stops of the pen-lever are mounted, which enables the instrument to be used as a sounder with equal facility, whether or not the operation of recording is going on at the same time.

NEW WRECKING INSTRUMENT.

This is a compact portable instrument (Fig. 7) in which all the working parts are of full size, but are so disposed as to occupy a minimum amount of space. It is much used in the railroad service for establishing temporary offices at points along the line, as in case of an accident obstructing traffic upon the road. It is desirable that an instrument

of this class should operate with all the convenience, facility and accuracy of a standard instrument, and yet be capable of being transported from place to place without inconvenience. This instrument is unusually well designed and merits special commendation.

FIG. 8.



THE ACME STEEL LEVER KEY.

The lever of this key (Fig. 8) is stamped from sheet steel instead of being of cast brass as in the old form of key. This gives the lever great strength, together with a certain slight degree of elasticity which

is regarded as important; while the weight to be moved is very small, a matter of great importance, as the operator in transmitting at the maximum speed of forty words per minute is required to make no less than fourteen or fifteen distinct movements of the hand per second and to maintain this continuously for hours. The design of this key is tasteful and the finish excellent. The binding posts for connecting the wires are placed upon the upper side of the base.

FIG. 7.

THE LATTIG KEY.

This key (Fig. 9) is the invention of a practical operator, and is provided with a supplementary or auxiliary circuit-breaking lever by which the separation between the contact points at the opening of the key is very largely increased, although the play of the key-lever itself is no greater than in the ordinary form. We regard this key as well adapted for use on lines on which a strong current is employed, and which have a great number of way-stations, conditions which exist upon many of the railway service lines.

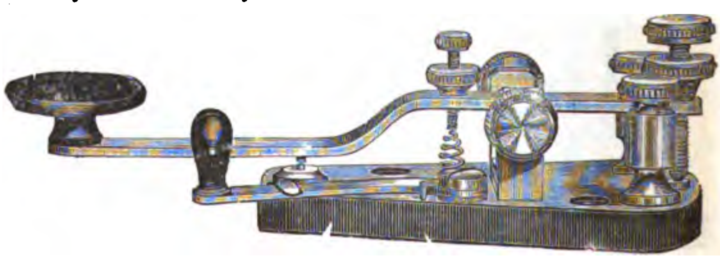


FIG. 8.

THE CUMMING PERIPHERY CONTACT.

This invention, exhibited by Cumming & Brinkerhoff, 219 E. Eighteenth street, New York, is an improved construction of contacts or electrodes for telegraphic circuit-breakers such as keys or relays. A key is exhibited (Fig. 10) which illustrates the application of the invention, which consists of two revolving discs or wheels which form the contacts, each of which is beveled down to a narrow edge on its

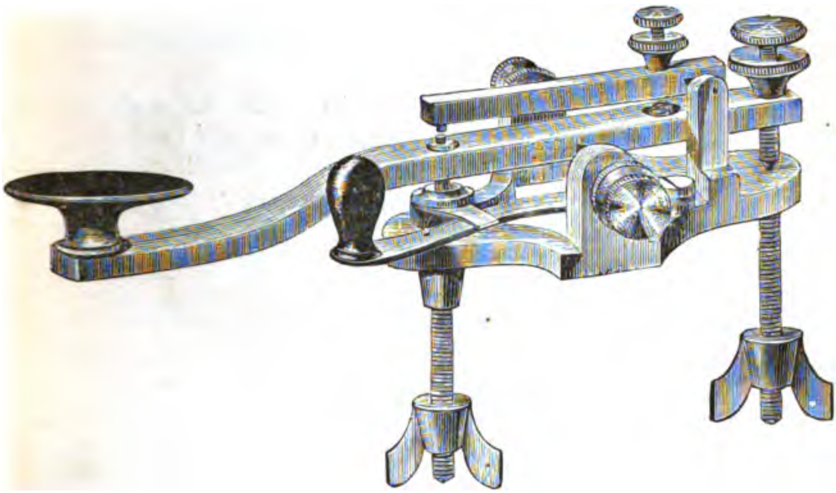


FIG. 9

periphery. The two disc electrodes are placed at right angles to each other, so that the actual contact is formed between two very minute surfaces. This form of contact appears to possess certain advantages, among which may be mentioned the adjustability of the discs, which

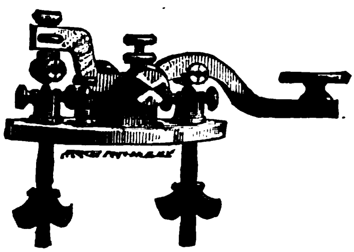


FIG. 10.

enables the point of contact to be changed at pleasure. Dust is also prevented from accumulating upon the contacts. There is a certain

elasticity in the system which avoids the concussion of the ordinary key upon a solid anvil which is found by experience to be so injurious to the muscles of the hand of the operator. A practical trial of the key by members of the committee who have been practical telegraphic operators, shows that it is an extremely pleasant one to manipulate. The same device has also been applied to the pole-changer for the transmitting apparatus in the quadruplex telegraph, on which currents of unusual strength from a dynamo-electric machine are employed.

The exhibitors of this invention give the following explanation of the theory of its operation:

In the ordinary contact, which is made by the flat ends of two platinum wires *J* and *K* (Fig 11), the electric current tends to jump

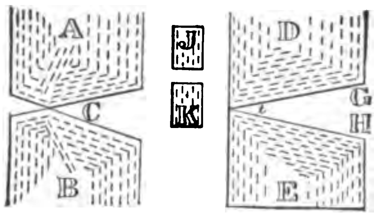


FIG. 11.

the intervening space (thereby forming an electric arc), for the two contact surfaces not being mathematically parallel can meet only at one point. Let this be at or near the centre *C*, the currents on the surface from *A* or *B* curve around to this point, approaching and attracting each other at all points, but joining only at one. If the contact is on one edge *t* the currents of *D* and *E*, in passing from *G* or *H* to *t*, must mutually attract one another; and the nearer *G* and *H* are to each other without touching the more liable the key is to "stick." In the case of two sharp cones or needles approximating as in Fig. 12, the currents pass almost straight to the apices *V* and *X* from *O*, *P*, *R*, and *S*, and therefore meet with no interference. The nearest approach to the needle point in practical application is the Cumming Periphery Contact of two discs set at right angles, as shown in Fig. 10.

THE VULCANIZED FIBRE COMPANY.

This company whose works are situated at Wilmington, Delaware, exhibits a number of samples of telegraph apparatus of different kinds manufactured by Patrick and Carter, in which the material commercially known as "vulcanized fibre" has been utilized as an insulat-

ing material, where such material is required, such as cases, bobbins and covers for electro-magnetic coils, etc.

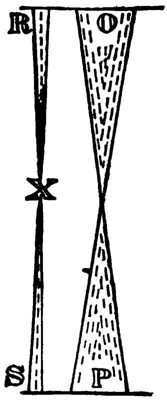


FIG. 12.

This material seems to possess many desirable characteristics for this purpose. It is made in three colors, red, white and black. It is much cheaper than vulcanized rubber, takes an excellent polish and withstands heat, very much better than rubber. It is an excellent insulator, except that in very damp places it absorbs moisture to some extent. This, however, does not affect its value for telegraphic apparatus, which is always carefully protected from dampness. We consider it admirably adapted for the purposes to which it has been applied in the exhibit under consideration.

M'CAUSLAND'S PRINTING TELEGRAPH.

This apparatus is designed for the rapid printing of quotations of the markets and exchanges, according to a system in extensive use in the larger cities of the United States.

Two line wires are employed, one for bringing the type wheel into position and the other for printing the successive letters as they are brought into position. The mechanism for advancing the type-wheel by the to-and-fro motion of the armature of an electro-magnet is a prominent characteristic of the machine. In the instrument now in general use this is effected by a driving escapement, consisting of a ratchet or pawl attached to and moved by the armature, and a ratchet-wheel with inclined teeth fixed on the type-wheel shaft. By this

mechanism, an intermittent advance motion of rotation is communicated to the type-wheel shaft. In the McCauseland machine this form of escapement is replaced by a small crank, which is caused to revolve by the reciprocating motion of the armature, and has upon its axis a pinion which engages with a large toothed wheel upon the type-wheel shaft. The application of this mechanism is exceedingly novel and ingenious, and would seem to possess at least one important advantage namely: that the motion of the type-wheel in passing from one letter to another is continuous and not intermittent. It thus not only utilizes the magnetic power (which is barely sufficient at most) to great advantage, as the type-wheel does not have to be started from a position of rest at each pulsation, but the momentum of the type-wheel tends to assist the action of the electro-magnet in case of an imperfect electrical pulsation. The platen for printing from either one of two parallel type-wheels, is an exceedingly novel, simple and efficient device. The type-wheel magnet is double, consisting of two magnets placed side by side and acting simultaneously upon one and the same armature. The electric current is divided upon entering the instrument between two branch circuits, half going through one magnet and half through the other. The inventor conceives that by this arrangement the force of the electrical current is compounded and that greater magnetic force is produced in all cases from a given current. This, however, depends entirely upon the ratio of the several resistances of the electro-magnet the line and the battery. The assumption is true under the particular conditions under which the instrument was exhibited, namely, a battery of small resistance and a line of inappreciable resistance. It would not be true under the conditions which must necessarily exist in actual service, and we do not regard this detail of arrangement as one possessing any value.

EDISON'S EMBOSSING TRANSLATING TELEGRAPH.

This apparatus is designed for the automatic retransmission of telegraphic messages at transfer stations. This work is usually performed by automatic repeaters, in which the receiving instrument of the one line acts as a key to re-write the commuuication, letter by letter, upon another line. In case it is not convenient to do this, the message is copied in the usual manner by the receiving operator, and then handed to another operator, to be resent upon the second line. Mr. Edison's

apparatus is designed to stereotype the received message upon paper in telegraphic characters. This stereotype may be used at any time thereafter for the automatic retransmission of its contents upon the same or another line.

The mechanism is very simple, consisting of a horizontal circular brass plate, having spiral grooves engraved upon its upper surface, which plate is capable of being revolved by an electric-motor. A sheet of soft paper is fastened upon the surface of the plate and revolves with it, so that the telegraphic characters, as received, may be embossed upon it by a stylus working into the spiral groove, in the manner of the ordinary telegraphic register. This circular sheet of paper, with the message embossed upon it in spiral lines, forms a stereotype, which may be used at any time to retransmit the message, by placing it upon the same or a similar plate and permitting the stylus to follow the indentations, by which a proper motion is imparted to it for making and breaking the circuit upon the second line, and thus the original signals are reproduced without possibility of error.

EDISON'S MOTOGRAPH RELAY.

This is a telegraphic receiving instrument, which is operated without the aid of electro-magnetism. It is based upon the fact, first made known by Mr. Edison, that an electric current passing from one to the other of two surfaces, in frictional contact with each other, materially diminishes the coefficient of friction. A small electric motor causes a cylinder of chalk to revolve against a rubber, to which rubber is attached the circuit-breaker by means of which the local receiving instrument is actuated. When no current is passing through the main line, the action of the friction tends to drag the circuit-breaker against its rear contact. As soon as the current flows, the friction is diminished to such an extent that it is overpowered by an antagonistic spring, which draws the circuit-breaker into contact with the stop which closes the local circuit. This is a highly ingenious apparatus, and is said to be capable of recording signals with much greater rapidity than any electro-magnetic instrument hitherto devised. It has not, however, been applied in practical use.

[Here follows a description of the advantages of the use of the Type Writer for reproducing the messages received at the various telegraph stations. For various reasons, among which, is the fact that the advantage could only be claimed for the reception of messages on telegraphic instruments which do not print. The Editing Committee has judged it expedient to omit this paragraph.—ED. COM.]

Respectfully submitted by

FRANK L. POPE (*Chn.*),
CHAS. J. SHAIN,
WM. H. GREENE,
E. ALEX. SCOTT,
H. W. SELLERS,
HUGO BILGRAM,
JOHN W. NYSTROM.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORT OF EXAMINERS

—OF—

SECTION XXI.

(SECTION IV., CLASSES III. AND IV. OF THE CATALOGUE.)

FIRE AND BURGLAR ALARMS AND ANNUNCIATORS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED IN THE JOURNAL OF THE FRANKLIN INSTITUTE, JANUARY, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXI.—FIRE AND BURGLAR ALARMS AND ANNUNCIATORS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXI, on Fire and Burglar Alarms and Annunciators.

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXI (on Fire and Burglar Alarms and Annunciators), respectfully present the following report.

DAVID R. WALKER, (*Ch'n*),

Examiners of Section XXI.

PHILADELPHIA, *December*, 1884.

FIRE AND BURGLAR ALARMS AND ANNUNCIATORS.

EXHIBIT OF THE WESTERN ELECTRIC COMPANY.

The Hotel Fire Alarm and Room Call, exhibited by this company, is designed for the following purposes: When a call is received in the office by means of the annunciator, the clerk, by pressing one of the push buttons, can signify to the guest that the call has been received and will be attended to. Should the clerk desire to ascertain whether a guest is in his room, he can press on the proper button of the room call, and the guest, by pressing upon the button in his room, can signify that he is in. The room call can also be used to call the guests at any time desired; when employed for that purpose, the bell being kept ringing until the guest announces that he is both awake and up, by signaling back to the annunciator, causing the bell in the office to ring and his drop to fall. In case of a fire, by moving a switch, a crank is set in motion and rollers upon the two ends, by pressing upon the push buttons successively, ring the bell in every room.

The chief advantage claimed for this system is that it requires only the same battery as is in ordinary use for the hotel call, and it is therefore subjected to daily tests; but where a large battery is required for the fire alarm, there is a liability that, in time of a fire, from being seldom used, it will be found out of order. While there is quite a similarity in hotel annunciators, in this one the arrangements are novel and the mechanism simple in its construction, so as not to be easily disarranged.

In the Burglar Alarm Annunciator, the indications are made by means of the needle annunciator. By the action of suitably arranged switches it is possible to connect to or disconnect from the alarm, any part of the house, at pleasure; the annunciator and bell can be connected to the alarm if desired, or the annunciator can be connected and the bell not connected, thus giving a silent alarm; or to show whether the strength of the battery is sufficient to work the alarm, it can be connected with the bell alone.

By the system of "Continuous Ringing," the bell rings whenever an opening is made, not only as long as the opening remains but until attention is called to the alarm and the ringing stopped by means of the restoring apparatus. By means of a switch on each machine, the "Continuous Ringing" system can be used, or not, at pleasure.

The chief advantage claimed for the Williams Mechanical Gong is that it requires but a very slight electrical current to release the mechanism, and the hammer being near the centre of the shaft on which it swings, is easily set in motion, so that as it approaches the gong, the centrifugal force carries it into position.

For the Haskins Turtle Gong it is claimed that the pivoting of the armature is such that a very slight electrical current will be sufficient to actuate it. With this is combined the advantage of economy of space.

EXHIBIT OF THE NOVELTY ELECTRIC COMPANY.

The Novelty Electric Company exhibit the following Fire and Burglar Alarm systems:

The fire alarm exhibited was patented by Mr. Ahearn, of Ahearn & Soper, Toronto, Canada, and is designed as a cheap and economical system for small towns. Signal boxes are located at convenient points: these boxes are in electrical circuit, with electro-magnetic bells, which are designed to be placed in engine houses, stores and private residences. The operation is simple and is as follows: The opening of the signal box door releases a weight, which, dropping, causes an armature to revolve between permanent magnets, which are similar in construction to the magnets and armature of the Bell magneto: this gives an effect the same as turning the crank of a magneto. On the spindle of the armature, or connected with it, is a small circular circuit breaker, which automatically signals the number of the station from which the signal has been sent upon all the bells with which it may be connected.

The burglar alarms exhibited were patented by D. Rosseau, of New York, and J. D. Lazelle, of New York, and contain the following important features: In addition to the alarm system, they have an attachment by which every door and window that is in circuit can be tested without the noise and annoyance of the bell ringing; this attachment is called a "silent tester." In the case there is also a clock which, besides being an ornamental time piece, automatically and

at any hour desired, opens all or any part of the house, and at the same time rings an alarm for the purpose of calling the occupants of a certain room.

Burglar Alarm, No. 2, has all of the above attachments, with additional attachments to awaken different servants, guests and household at different hours.

Burglar Alarm No. 3, in addition to the attachments of No. 1, has the advantage of a gas connection, which works in conjunction with indicators or drops, so that in case a burglar opens a door or window, he not only rings the bell and drops an indicator, but also lights the gas and reveals his exact position.

Burglar Alarm No. 4, merely communicates an alarm without giving any indications from what particular point it comes. In order to locate the point of alarm the switches must be turned on the face of the alarm, when the correct one will stop the ringing of the bell. The annunciators are of the shuttle-drop kind, not complicated nor easily put out of order, and are claimed to be effective.

APPLEGATE'S ELECTRIC FLOOR-MAT ALARM.

This system comprises essentially an electric alarm bell, a mat-carrying circuit, and closing and breaking devices, so that when the mat is subjected to pressure the alarm will be sounded. The mat consists of narrow strips of wood connected to a fabric backing, and on the strip side of the mat is a series of springs which support the mat, there being two separate wires and the springs being securely connected to each wire. When the mat is stepped upon these springs are compressed, contacts are made, and a current is sent through the connecting wires (which are embedded or grooved in the wood) to the bell electro-magnet, so as to sound an alarm. The bell has a switch or lever on the frame, by means of which, when moved, the vibrating adjustments are displaced and the current ceases to flow through the armature spring or circuit breaker, then passes directly through the magnet, and upon the movement of this switch or side lever, it greatly lengthens the stroke of the armature, which is essential when a single stroke only is desired. The same lever that lengthens the stroke switches the current directly through the magnet closing the circuit, attracting and holding the armature. The reverse movement of the lever readjusts the bell as a complete vibrator with a short stroke.

There is also a further improvement, "automatic," in the form of a ratchet wheel which revolves by the movement of the armature by means of a pawl, the wheel revolving upon a projection from the bell frame. The wheel has a pin, or pins, inserted and properly insulated from it. As the armature vibrates, the wheel revolves and one of the projecting pins comes in contact with two delicate springs sending the current directly through the magnet and holding the armature, acting automatically and giving a short sound of the alarm with the circuit still closed at the mat or other circuit-closing devices. When the circuit is broken at the mat it is also broken at the two small springs on the bell ready to repeat the short alarm upon closing the circuit, thereby preventing an annoyance while the distant points may be connected.

A padding is used, in connection with the mat or matting, comprised of four thicknesses of paper, glued together, known as carpet padding pulp paper. Each of the strips of different width; thus, by laying it at the outer edges, graduating the carpet and hiding the mat, and, in addition to the finish, preventing the mat from cutting the carpet or other covering.

The mat exhibited is intended for use on an open circuit, but can be used also on closed circuits.

The advantages claimed for this system are security, portability, cheapness and convenience. The mats may be placed beneath the carpet and the wires entirely concealed so that the burglar has no chance of rendering the device inoperative by cutting the wires, while a few pieces of the matting placed in different portions of the house would provide ample protection. The mat alarm affords the same protection, whether the doors or windows are closed or open, and therefore interferes in no way with the proper ventilation of the house. The system is available as a call for stores, offices, banks, etc., as well as for a burglar alarm. As the mat can be put down and taken up without trouble, and as the wiring is very simple, it can be readily transferred from one house to another. We append a copy of the patents which explain the accompanying diagrams.*

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* Here follow copies of the drawings and specifications filed in the following patents: 195,074, September 11, 1877; 240,939, May 3, 1881, which the committee does not deem it necessary to re-publish.

EXHIBIT OF THE AMERICAN DISTRICT TELEGRAPH COMPANY.

The District Call system may be described as follows: A box contains a clock-work, which, when wound up, by the turning of a crank or handle on the outside of the box revolves a circuit-breaking wheel upon the periphery of which rests a connecting spring. When the crank or handle is placed at the word "messenger" and released, the revolution of the circuit wheel causes the connecting spring to drop into slotted or open spaces and breaks the main circuit and the signal of the box, thus arranged is received at the district or central office upon a relay, the back action of the armature of which closes a local circuit acting upon a bell and register and recording the signal. When the crank is placed at the word "police" and released, the circuit wheel makes two revolutions causing two registrations of the signal.

The several calls for which the box is arranged are determined by the number of times the signal is received at the central office.

It may be noted that all "call" signals end with an even figure to distinguish them from the burglar alarm signals which end with an odd figure. This system of calls being the usual method adopted by all District Telegraph Companies, for signaling from a distant point to a central office. No special claim is made for it excepting as it enters into the arrangement of the following described exhibits:

THE CLOSED CIRCUIT BURGLAR ALARM SYSTEM.

The doors and windows having been connected by closed circuit springs to the burglar alarm box placed in the building, the action may be substantially described as follows:

The box contains the circuit-breaking wheel before described, a pair of magnets to actuate an armature and a pivoted shaft to hold the circuit wheel in check. The main circuit is brought in and connected to each side of the pair of magnets,—after passing through the circuit wheel and connection spring, and, at these points the shunt or wire passing through the building and fastened to the spring, is also connected. When the shunt is closed by the closing of each and every door and window, the clock-work is wound up and the circuit wheel is caught and locked by the pivoted shaft, at the same time a plate drops in front of an opening in the box face and shows the word "set." The main circuit now passes from the point of connection over the

shunt, which offering a very much less resistance than the magnets cuts them out so long as the shunt is kept closed. Should any door or window now be opened, and the shunt be broken, the circuit passes through the magnets, attracting the armature which trips or throws off the detaining shaft and releases the clock-work. The magnets having performed their work, are, by a very simple device, cut out of the main circuit, and the circuit wheel and connection spring are alone left in the line circuit.

By the use of a simple device the magnets may be thrown into circuit, the box not being wound up, and should any portion of the shunt be open the armature will be attracted and a clicking sound be heard, which will not be possible if the shunt is closed and intact. The signal of the burglar alarm is transmitted five times. It is claimed that this system is a perfect closed circuit "alarm," by which it is not possible to leave any portion of a building, connected by this method, open or unprotected, as the shunt must be closed in its entirety to wind up and "set" the alarm box.

The protective or cabinet system consists of a wooden case or covering, the inner surfaces of which are lined throughout with wires, which, being securely fastened in both directions upon the surfaces, forms a perfect protection. This case may be used as a cabinet, simply, or as an enclosing case for a safe. It is connected by wire with a central office having special appliances for receiving notice of the closing as well as the opening of the case. It is claimed for this system that it is a perfected method of protecting safes, vaults and rooms by an electric covering which cannot be broken through, cut out of circuit, or in any manner tampered with, after having been closed and placed in connection with a central office, by any one—expert burglar, electrician, or any other person.

THE POLICE SIGNAL SYSTEM OF THE MUNICIPAL SIGNAL COMPANY OF BOSTON.

This system provides means of intercommunication between the policemen on their routes and the commanding officer at the police station, by signaling apparatus designed for the purpose and also by telephone, the latter being used solely as an adjunct to the signaling portion of the system. The exhibit comprises a station house apparatus and a policeman's beat equipped with two signal boxes or stations

and a telephone station, the stations being connected with the station house instruments by two metallic circuits, one for signals and the other for telephones. The station house instruments consist of two relays, one on each side of the signal circuit, their armatures controlling two ink recorders after the manner of district or fire alarm telegraphs. One of these recording instruments registers the "on duty," or "patrol" signals of the policemen, while the other only records the "alarm" signals. The signals are regulated by the introduction of a greater or less resistance, the less resistance being used for the patrol and the greater for the alarm signals. The station house is also provided with a transmitter capable of transmitting any one of a hundred numbers, and it is provided with an index dial and pointer for convenience in setting it in position to transmit any desired number. The transmitter itself is of ingenious construction, being a concaved drum, having the circuit controlling contact points for each number grouped thereon longitudinally, the various signals being arranged side by side round the drum. Four revolving arms, moved by a clock-work motor, controlled by detents and having flexible contacts at their extremities, which, when revolved, successively co-operate with the contact points on the concave surface of the drum, close and open a local circuit controlling a pole changer whereby the main battery on the signal circuit is reversed whenever the revolving contact in co-operation with one of the drum contacts, closes the local circuit of the pole changer. The street signal boxes, when their doors are open, expose dials having nine different signals or calls conspicuously displayed thereon, such as "Aid," "Wagon," "Riot," "Ambulance," etc., and should a policeman require "aid," "wagon," or anything inscribed on the dial, he has merely to move an index finger to that desired, and then give the alarm, which causes characters, such as dots and dashes to be transmitted over the circuit and recorded at the police station, indicating to the person in attendance the nature of the aid and the locality where it is wanted. The closing of the door of the signal box restores the indicator to its normal position. Citizens may have keys issued to them, numbered and registered at police headquarters, and they can give a police alarm from any signal station by merely inserting the key in a "citizen's keyhole," underneath the door of the signal box, turning it as far as it will go, and then releasing it, and a policeman can likewise, in an emergency, give a call for

assistance in like manner, without being obliged to open a door of any kind.

The telephone stations, as shown in this exhibit, are separate from the signal stations, but they each bear a number to distinguish them from each other, as do also the signal stations. It is claimed that the telephone stations can be combined with the signal stations.

Policemen can send in their "on duty" signal from the signal boxes in rotation, at certain definite times, and these signals are received on the patrol register at the police station, and, at the same time, the transmitter is automatically brought into action and transmits over the circuit whatever number is in position for transmission, ringing it on a bell inside of the street signal box, by means of a polarized magnet and armature, the policeman being informed by the number he hears whether he is wanted at the telephone or at some other signal station.

The chief merits claimed for this system are: complete control of the policemen by their commanding officer; rapid and efficacious communication of policemen and citizens with police stations, and separate and independent recording instruments for alarms and "on duty" signals on a single circuit. It is also claimed that if an "on duty" signal and a "call" signal be given simultaneously that the "call" signal will be registered notwithstanding the "on duty" signal, the interference not affecting the more important, or "call" signal, owing to the higher resistance introduced into the circuit.

The mechanism by means of which the signal boxes are operated was not shown to the committee.

THE PORTER AUTOMATIC ELECTRIC SIGNAL AS A FIRE ALARM SYSTEM.

The principle of the circuit is known as the earth or ground connections; that portion, however, which is outside of the office is metallic, the grounded ends being under control of the operator at the station.

At each end of the circuit there is a system of relays and local signal. On one of the ends there is a rheostat for the purpose of increasing or diminishing the resistance of the circuit. The ordinary method for using this is to "put in" as much resistance on the rheostat end of the circuit as will enable the tension spring of the relay at the outgoing end of the circuit to overcome the magnetic attraction on the armature, thus holding it away from the poles until the resistance in

the circuit is reduced when the magnetic attraction will overcome the tension spring and a local alarm is the result. The relay on the rheostat end of the circuit is operated just the reverse of the one at the battery end, the adjustment being made so that the magnetic attraction barely overcomes the tension spring; so that the slightest falling off of magnetic attraction will permit the tension spring to draw the armature back, when the other local alarm system will be operated.

Each signal box has an earth connection, which is brought into use only when the box is operated so that, by giving a signal, a ground is established through the circuit breaking wheel, the circuit being broken by the same operation, as the wheel revolves, the combination giving the number of the box is consecutively made and repeated three times. It is claimed for this system of signaling that on one side the circuit might be entirely destroyed, while the signal would come into the office all right on the other side. It is also claimed that the operator is made aware of the slightest changes in the condition of the circuit and without leaving his station can instantly switch in a reserve battery or even utilize a "ground," "break," or "cross" to do the work of signaling.

EXHIBIT OF PARTICK & CARTER.

The novelty of device, mechanism, etc., which is claimed for the annunciators and alarms in the above exhibit, are:

1. A perforated zinc plate acting as a dial and support for the pointers, and in the smaller size performing the part of tripping or restoring mechanism without any farther mechanism being necessary than a pair of hinges at the top of plate. The plate, or dial on being moved forward, breaks the contact between the pointer and the magnet core; no amount of jar or hard usage will throw this plate out of place or adjustment, a very important point when the rough handling of kitchen and other annunciators is so apt to throw delicately constructed mechanism out of order.

2. The small number and great simplicity of the parts, there being only one magnet and a pivoted needle or pointer necessary for each indicator or number, thus reducing the number of parts to a minimum, the simple pointer doing the work of several parts.

3. In the large or hotel annunciators the same mechanism is employed as in the smaller, with the exception that the dial is stationary,

the tripping mechanism being merely a system or number of brass strips carrying pins projecting through slots in the dial. These pins press the pointer away from the magnet core whenever the trip handle is moved. Only the pointer that is indicating is moved by this arrangement.

4. Owing to the extreme simplicity of this apparatus a very small battery power is required to operate the annunciator.

5. All bells placed in these annunciators are mounted on iron frames, so arranged that it is almost impossible to put them out of adjustment.

6. The needle or pointer can be made of steel or iron, as permanent magnetism is not depended upon to cause it to adhere to the core of the magnet, residual magnetism being sufficient.*

The committee regret that they were not furnished with more lettered diagrams of the exhibits as thereby the explanations could have been more clearly set forth.

In some instances it was found that the persons in charge of the exhibits were not as fully competent to explain the workings thereof as the committee would have desired.

The foregoing report is respectfully submitted by

DAVID R. WALKER, *Chairman.*

WM. ATLEE DRYSDALE,	HUGO BILGRAM,
DAVID BROOKS,	LOUIS H. SPELLIER,
E. ALEX. SCOTT,	THEO. D. RAND.

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* Here follows a diagram of the connection for the Patrick & Carter alarm, which the committee does not think it necessary to reproduce.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXII.

(SECTION IV-A, CLASSES V, VI, VII OF THE CATALOGUE.)

Electric Signaling Apparatus.
Electric Registering Apparatus,
Etc., Etc.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, JANUARY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,

CHARLES BULLOCK,

THEO. D. RAND,

COLEMAN SELLERS,

WILLIAM H. WAHL.

1884-INTERNATIONAL ELECTRICAL EXHIBITION-1884

OF THE

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA.
FOR THE PROMOTION OF THE MECHANIC ARTS.

SECTION XXII.—RAILWAY SIGNALS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXII on "Electric Signaling and Registering Apparatus." Respectfully, M. B. SNYDER.

Chairman Board of Examiners.

PHILADELPHIA, December, 1885.

CAMBRIDGE, Mass., September 1, 1885.

PROF. M. B. SNYDER, *Chairman of the Board of Examiners.*

DEAR SIR:—I hand you herewith the report of the Examining Committee in Section XXII.

Yours respectfully,

.WM. A. ROGERS,

Chairman of Section.

SECTION XXII.

The Examining Committee of this Section unanimously decided that—

(1.) The Committee be divided into sub-committees, as follows:

Sub-committee I, Railway Signals, Prof. W. A. Rogers, Chairman; Messrs. Dolbear, Fiske, Kintner, Penrose, Phillips and Plush.

Sub-committee II, Time-pieces, Prof. Waldo, Chairman; Messrs. Harrington, Harkness, Kintner and Rogers.

Sub-committee III, Chronographs, Prof. Harkness, Chairman; Messrs. Harding, Kintner, Paul and Van Dyck.

Sub-committee IV, *Meteorological and other Registers*, Prof. Harrington, Chairman; Messrs. Allen, Draper, Heap, Paul and Waldo.

(2.) It was voted that, in the reports of examination of exhibits submitted to this Section, there be no direct comparison of the exhibits to the detriment of one and praise of another, but that all reports be analytical and descriptive in their nature, and point out the ascertained efficiency or inefficiency of the apparatus examined.

(3.) It was voted that all the reports of sub-committees should be signed by the examining officers and submitted to the whole section for discussion, modification and approval.

(4.) Prof. Waldo was, at his own request, excused from reporting on the exhibit of the Time Telegraph Company.

M. W. HARRINGTON,

Secretary of Ex. Com. of Sec. XXII.

REPORT OF SUB-COMMITTEE ON RAILWAY SIGNALS.

Three systems of signals were entered for examination, viz :

(1.) The system of the Union Switch and Signal Company, of Pittsburgh, Pa.

(2.) The Hall System, exhibited by the Wharton Switch and Signal Company.

(3.) The Putnam System of Audible Signals, exhibited by the Railway Cab Electric Signal Company.

The examination of these systems will proceed in the following order:

(*a.*) Statement of the fundamental principles employed.

(*b.*) Statement of the results claimed to be accomplished.

(*c.*) Description of the methods and mechanical devices employed.

(*d.*) An examination of the performance of the system in the experience of the railroads upon which it is in operation.

THE UNION SWITCH AND SIGNAL COMPANY.

(*a*) The fundamental principle upon which this system rests is a *closed rail circuit* for a distance determined by the relation between the intensity of the current developed by the battery and the distance at which the greatest efficiency is maintained. From experience, it has been found that this distance is from one to two miles.

(*b.*) It is claimed for this system:

(1.) That the condition of the track in a given section is shown, without chance of failure, indicating also whether it is occupied by a full train, or any part of a train. Any interruption of the constant current supplied from a battery, at one end of a section and a signal magnet at the other end, displays a danger signal. These signals will be shown

(*a.*) When a train on entering a section making a metallic connection between the rails through the wheel and axle demagnetizes or shunts the signal magnet.

(*b.*) When there is a broken rail or a misplaced switch in the section, and when there is a train on a side switch not clear of the fouling point on the main line, without regard to the position of the switch.

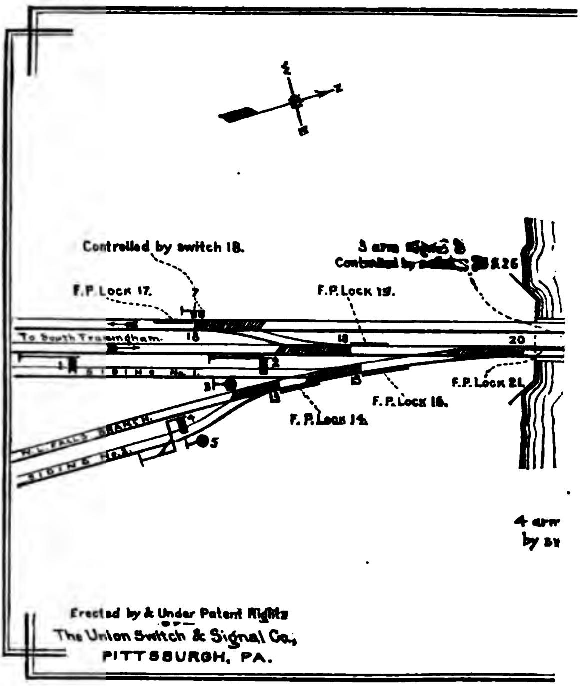
The mechanism employed in the interlocking and block signaling systems of signals exhibited by this company are described as follows:

ing of such signals, by the movement of their p

REPORT OF SUB-COMMITTEE ON RAILWAY SIGNALS.

Three systems of sig[illegible]d for examination, viz :

International Electrical Exhibition



tion, and when there is a train on a side swit[illegible] ...ing
point on the main line, without regard tc[illegible] ...itch.

The mechanism employed in the interlocking and block signaling systems of signals exhibited by this company are described as follows:

INTERLOCKING AND BLOCK SIGNALING.

The accidents that are constantly occurring, at grade crossing junctions, draw-bridges, and where there are numerous switches, have rendered the use of some system of appliances for the prevention of such accidents absolutely necessary.

A number of railways are now giving attention to this subject and are introducing what is known technically, as "Interlocking" and "Block Signaling Apparatus," for the prevention of accidents.

INTERLOCKING APPARATUS.

"Interlocking Apparatus" is the term applied to devices used for the movement, from a common point, by a single operator, of a number of switches and signals in safe order, so that trains may be allowed to proceed without danger, after having received a safety signal.

The best form of apparatus known up to the present time, and which has been worked to very great perfection in England and this country, is the Saxby & Farmer.

Where such apparatus is used, each switch and signal is provided with a moving mechanism, the operation of which is governed by the operator, through suitable connections, from a common point, usually termed a "Signal Cabin, or Tower."

The cut, *Fig. 1*, shows an arrangement of switches and signals where interlocking apparatus is used to advantage, there being twelve switches and thirty-one signals, which have to be moved in a certain predetermined order.

The connections (of rods or wires) from the switches and signals are attached to a system of levers arranged in a frame-work, as shown by *Fig. 2*.

This frame-work is located in the tower and the levers are provided with interlocking apparatus, so arranged, that the switches and signals can be moved only in a safe order; that is, the required switches must first be set and locked in their proper positions for the train movement, which is about to be performed, before the signals can be given to allow the train to proceed; and the clearing of such signals, by the movement of their proper levers, locks

the apparatus so that the switches cannot again be moved until the signals have been restored to the "danger" position.

The interlocking devices on the machine have been worked to such perfection that any required combination of switches and signals (for one or more trains at the same time) can be made, while the levers governing conflicting movements are absolutely locked.

This interlocking apparatus is also so constructed that even where several switches and signals are to be moved for one train operation, the movement of these switches and signals in a proper order is regulated, and this order may be in accordance with the rules of any railroad.

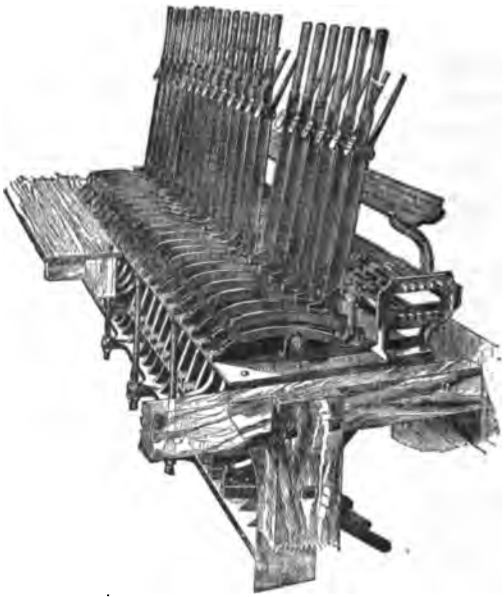


FIG. 2.

The constant use of interlocking apparatus, such as the Saxby & Farmer, and kindred appliances, has led to great perfection in every detail; such as the proper arrangement and construction of the connections from the "tower" to each switch and signal, the devices for compensating for the expansion and contraction of such connections, and the locking devices for the switches, as well as the interlocking apparatus on the machine in the tower.

From the foregoing brief statement, it will be seen that the clearing of signals for a train to proceed locks the switches over

which the train is to pass; and it necessarily follows that restoring these signals to "danger" will unlock at least one of the switches in the combination, the movement of which in turn will unlock the next switch, and so on.

In order to prevent the movement of switches under passing trains, "detector bars" are arranged in connection with the switch locking apparatus, in such a manner, that the unlocking of the switch cannot take place so long as the train is passing such bar. This "detector bar" is a piece of iron about forty-five feet in length, or of a length greater than the distance between the trucks of a car, and is hinged along the rail and connected to the lock of the switch.

The use of the detector bars became necessary in connection with switches, because of the liability of operators to move switches before the last car of the train has passed.

"Interlocking Apparatus" of the kind above described is that now commonly used on all the English railways.

But with all such appliances there has, however, been lacking some device, out of the control of the operator, which would prevent him, if confused or not being able to see clearly, from giving safety signals when the track on which the train is to pass is occupied, or obstructed by another train or car standing upon a siding in such a position as to cause a collision.

ELECTRIC LOCKING OF THE INTERLOCKING APPARATUS.

The Union Switch and Signal Company are attaching, in connection with the various interlocking apparatus, which they are manufacturing, automatic electric appliances, which absolutely prevent an operator from making a mistake; and the system by which this is accomplished is known as the "Electric Locking of the Interlocking Apparatus."

This Electric Locking Apparatus has now been used a sufficient length of time to show that it is an absolute safeguard against mistakes on the part of the operator; and the claim is made by those who have had experience with interlocking, with and without it, that interlocking apparatus may be a source of great danger, unless provided with this additional safeguard, inasmuch as in the one case, an operator may, without design, cause a serious acci-

dent, while with the electric locking he is powerless to give clear signals, except when the track is absolutely clear.

The perfect electric locking, as above described, depends upon the use of what is termed the "track circuit system." In this system, the rails of the track are utilized as electric conductors, in such a manner that, if any portion of the track or sidings to be guarded, is occupied by even a pair of wheels, the interlocking apparatus in the tower is automatically locked and kept locked until the electric current is restored to its normal channels by the removal of the obstruction.

The system of interlocking has grown, step by step, from the movement of one switch and its signal, to the movement of a number of switches and signals in complicated yards.

The various additions to the system, made as a result of experience, have led to a development of "the art," and have shown to those who have followed their introduction the various safeguards that have been needed to render the system absolutely safe.

The enormous number of patents taken out for interlocking apparatus shows that the subject has been studied in all its phases, but until the present time (with the exception of the hydraulic apparatus) the interlocking has remained of what might be termed the mechanical form; that is, an arrangement of levers, rods and wires moved by hand, as hereinbefore described.

The hydraulic system has received great attention, and has been perfected in all its details, so as to accomplish, by means of hydraulic pressure, what has been accomplished by the mechanical.

The complicated system of switches at East St. Louis, with the necessary signals, is operated by the hydraulic system, eighty-four levers arranged in a tower being capable of moving as many switches and signals as could be moved by 200 Saxby & Farmer levers.

Within the last two years several of the leading railroads of the country have put in appliances for operating switches and signals, known as the Westinghouse Pneumatic Interlocking Switch and Signal System. In this system, the experience gained in the use of compressed air for automatic railway brakes has been taken advantage of, and the working of this new system will be watched with great interest, because of the many advantages which it will possess over any other known form of interlocking. In this system,

compressed air furnishes the motive-power for operating the switches, signals and locks, and electricity is used for the purpose of locking or unlocking the apparatus moved by the operator, and also for bringing the compressed air into use for the operation of signals.

By the use of electricity, it has been possible to provide locking apparatus, in connection with each switch and combined with the machine in the tower, for preventing the complete movement of a switch lever by the operator, until such switch has not only been moved to, but absolutely locked in, its proper place It has also been possible to prevent the clearing of signals until the switches have been moved and locked in their proper positions, for the clearing of the signal is made dependent upon the locking bolt being moved entirely to its seat. Also, in this new system, the clearing of the signals automatically locks the levers in the tower, and holds them locked, until the required train movement has been performed, and until the signals have been restored to their danger positions; the unlocking depending, not upon the movement of the lever in the tower for putting the signal to "danger," but upon the signal itself assuming its "normal," or danger position.

To this apparatus there is applied the "track circuit system" of locking, whereby the operator is prevented from making conflicting train movements, or giving "clear" signals, or moving switches, unless the track over which the train is to pass is clear.

By the use of compressed air as a motive-power, the labor attending the operation of switches and signals is reduced to the simple movement of miniature levers. The mechanism in the tower, for the operation of a large number of switches, is brought into a very small space, while the movement of switches and signals is rendered possible at distances which could not be attempted, were their operation to depend upon the movement of long rods or wire connections.

By the use of this system, the connections for the transmission of the power (being pipes and insulated wires), may be placed underground, so that they cannot be interfered with; but whether buried or not, they are unaffected in operation by extreme changes of temperature.

The machine in the tower, for moving the switches and signals in a prescribed order, is so constructed that changes in combi-

nation are easily effected, and a machine can be put in the tower which will be large enough for any possible addition to the number of switches and signals to be operated, without materially increasing the first cost of the apparatus; and the position of switches and signals can be changed with little expense, as compared with that necessary where the mechanical systems are used.

BLOCK SIGNALING.

"Block signals" is the term applied to a system of signals, the use of which is to prevent two trains from being upon a certain section of railroad at the same time.

These signals are moved by hand, by operators placed in suitable towers, and these operators are supposed not to give a "clear" signal for a train to proceed on a section until the train that has been admitted has passed beyond the next succeeding station, and the operator in that section has notified the first operator, by telegraph, that the section is clear.

This system is in general use on all the railways in Great Britain and many other European railways, and has been adopted to a limited extent on some of the leading railways of the United States.

The use of this system, however, has shown that it is imperfect, inasmuch as one operator can give misleading signals and thereby cause serious accidents.

To prevent mistakes on the part of the operators, a system known as the Sykes has been perfected.

THE SYKES SYSTEM OF LOCK AND BLOCK SIGNALING

The three cuts, *3*, *4* and *5*, with the following description, will illustrate the working of this system. Each of the three cuts relate to the same three signals, as will presently be explained.

The railroad is supposed to be divided into sections, at the beginning of these sections, as at *A*, *B* and *C*, is arranged a signal post having semaphore arm *S*, the normal position of which is as shown in *Fig. 3*, indicating "danger," or "stop," to a train.

Adjacent to each of these signal posts is a tower, not shown on the illustration, in which there is located a lever *E*, having a suit-

able connection leading to the signal post, whereby the semaphore arm S is operated. This lever E, carries with it a sliding bar F, having a locking device, indicated by G, capable of locking the lever E into either of two positions. In the tower is located a box a, having suitable electric and mechanical connections for operating two indicators, R and R, which are displayed through suitable openings cut in the face of the box.

In addition to the indicators in the box, is a small semaphore indicator D, placed on top of the box for indicating to the operator the position of the next signal arms S ahead. This has suitable electric connections for its operation

The indicator R reads either "clear" or "blocked," and refers to the condition of the section of track in the rear.

The indicator R is connected with the lock G in such a manner that when it reads "clear" the lock G is lifted, and the lever E is free to be moved by the operator, but when it reads "blocked," the lever E is locked.

The normal position of all the semaphore arms S is "danger;" all the levers E are "home" and unlocked; all the indicators R read "clear;" all the indicators R' read "train on;" and all the indicators D have their arms up at right angles, as shown at Station B, in *Fig 3*. A train at A being ready to start, the lever E is pulled over, thus dropping the semaphore S, after which the train may start.

The indicator R at A now reads "blocked," the indicator R', "train on," and the lever E is automatically locked. When the train passes the track treadle T, the lever at A is unlocked, and may now be returned "home" by the signal man, when it will again be automatically locked. The parts are now in the positions shown in stations A, B and C, in *Fig. 3*. When the train approaches Station B, the signal man there (having previously been notified by telegraph of the approach of a train) pulls over his lever E, and drops his semaphore S, that the train may pass. This motion changes his indicators in the same manner as at A, and locks his lever E in its "clear" position. The parts are now as shown at stations A, B and C, in *Fig. 4*. Meanwhile the lever at A remains locked; and to unlock it, the operator at B must press in the knot or plunger indicated at M, which is arranged on the front of his indicator case; but this he cannot do until his

lever has been unlocked and returned to its "home" or normal position. When the train passes the treadle T, of block B, the indicator R shifts to "clear," and the lever E is unlocked, and then may be returned "home." This act sets the indicator R to "blocked" again, locks the lever E, and sets the indicator R' to "train passed;" it also sends an electric current through the indicator D, at station A, in such a manner that its arm drops to indicate that the section between A and B is "clear." The parts are now as shown at station A, B and C, in *Fig. 5*. The operator at B may now unlock A's lever for another train, this he does by pressing in the plunger M, which sends an electric current to block A, unlocks the lever E, shifts the indicator R at station A to "clear," and causes the arm of indicator D at B to fall "clear." When B presses the plunger M and it springs back, his indicator R' shifts to "train on" (meaning that the section from A to B is in condition to receive a train), and it is then locked, so that the plunger cannot be worked again until the lever E has been pulled over and returned; and the lever E remains locked until the train has passed the treadle T at station C and the operator has pressed his plunger M.

Should another train approach B from A before the operator at C has thus unlocked the lever E at B, the semaphore S at B cannot be lowered (even should he attempt to do so), and the train must stop until the lever is unlocked by the operator at C. Thus, it is evident that it is not possible for one train to approach nearer to another than the distance between two signal stations.

It will be seen that in this system is an absolute safeguard against operators giving wrong or misleading signals, and accidents will be prevented, unless the trainmen wilfully disobey the signals which are displayed for their protection.

AUTOMATIC BLOCK SIGNALS.

It often happens that trains are required to run much closer together than the distance between the telegraph stations on railroads, and in such cases it is important to establish an automatic system of block signals, which will provide for shorter blocks and prevent two trains from being on the same block at the same time.

Automatic signals of this kind have been experimented with and tried by a number of the leading railways in the States.

"The Rail Circuit System" seems to be the only automatic system that fully meets all of the requirements.

In this system, the line of track is divided into block sections, of a mile or less in length, and the rails of each of these sections are prevented from electrically joining the rails of the next section

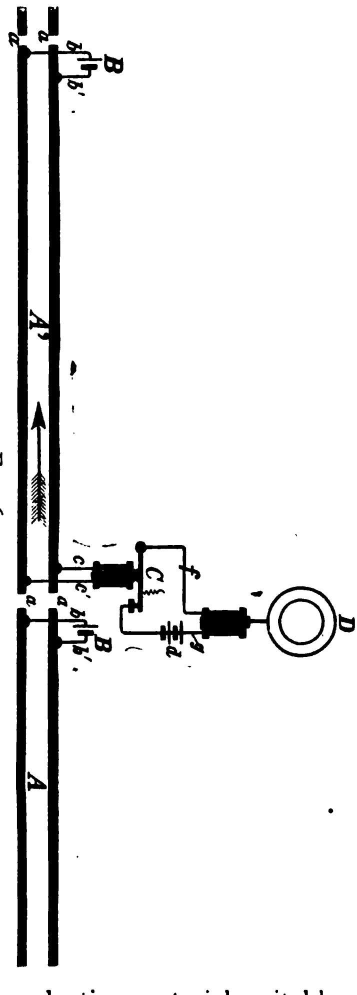


FIG. 6.

by the use of non-conducting material, suitably placed at the junction of the two sections. The rails of each block section are electrically joined one with the other, by means of wires, which are attached to rivets and driven into the flanges of the rails, near their ends. Referring to *Fig. 6*, the two broad lines represent the lines

of rail (of one track of a double track road). The track insulations between this and the adjacent sections are indicated by a. The battery B, has one pole connected by wire b to one rail and its opposite pole by wire b' connected to the other rail. At the beginning of the section is arranged an electro-magnet C, having one wire c connected to one rail and its second wire c' connected to the opposite rail; thus establishing an electric circuit from the battery, through wire b', through one rail, through wire c, through magnet C and the wire c' to the other rail, and then by wire b to the battery.

This electric circuit is known as a constantly closed circuit, and

FIG. 7. "C" Signal Open.

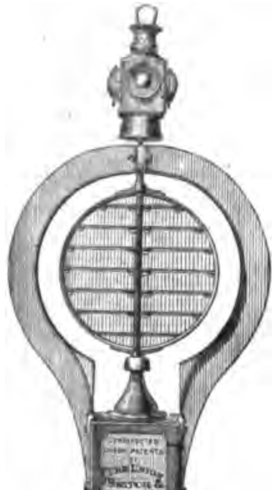


FIG. 8. "C" Signal Closed.

unless the electric current is interrupted, the armature of the magnet C is held to its seat, and establishes a second electric circuit through the magnet of the signal mechanism D, from the battery d by wires g and f. If the current through magnet C is interrupted, the armature of the magnet C is drawn from its seat by a spring, or is arranged to fall from its seat by gravity, in such a manner as to interrupt the circuit from the battery d, causing the signal D to turn to the position indicating "danger," restoring the circuit from the battery d, restores the signal D to its safety position.

Figs. 7 and 8 show the form of signal D. The electric mechanism is contained in the box at the lower part, which causes a disk to

be turned, in *Fig. 8*, to indicate "danger" and as shown in *Fig. 7* to indicate "clear."

The clock work and the weight furnishes the motive-power for turning the signal, and the electric current, through the magnet of

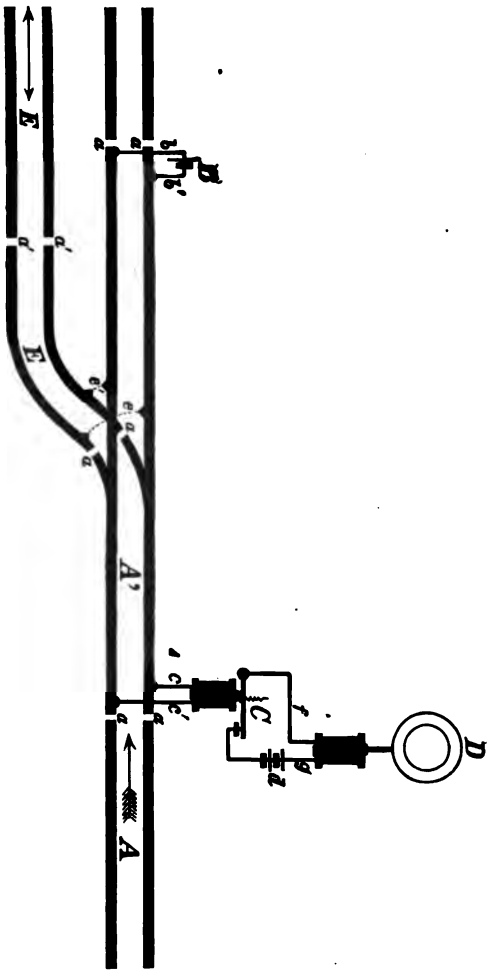


FIG. 9.

D, releases the proper mechanism for the operation of the signal. So long as the current passes through the magnet at *D*, the signal will stand to "clear," as in *Fig. 7;* any interruption of the current will cause the mechanism in the box to so operate as to turn the signal into position shown in *Fig. 8*, to indicate "danger."

From this description, it will readily be seen that if a wire from the battery *B* to the rail be broken, or if a rail be removed or broken, so as to interrupt the electric current, the signal *D* will instantly turn to "danger."

Similarly the signal is turned to danger by a pair of wheels joining the two rails of the section, for a pair of wheels and its axle has the effect of forming a "short circuit," so that the electricity, instead of passing from the battery *B* through the magnet *C*, passes to the wheel on one side, through the axle and wheel to the other rail back to the battery, which has the effect of releasing the armature of the magnet *C*, thereby turning the signal *D* to danger, the same as if a rail had been removed or broken.

Fig. 9 shows an arrangement of signals on a section, having a switch or branch. Part of the siding *E* is insulated at *a'*, the same as the main track. The rails of the main section *A'* and the branch *E* are joined by wires *e*, *e'*, in such a manner that a pair of wheels entering upon the branch *E* has the same effect as entering upon the main line; that is, to "short circuit" the current from the battery *B*, in such a manner as to turn the signal *D* to "danger." The insulations *a'* in the branch *E* are placed at a point a sufficient distance from the main track to insure a "danger" signal being given if a car or an engine stands too close to the main line upon the siding.

These two cuts and the description illustrate the principle of operation of the constantly closed "rail circuit system" of block signals.

Fig. 10, shows three such signals, with each signal, *D*, D^1 and D^2, placed a sufficient distance from the beginning of each section to enable a train to stop, after having discovered the signal at danger before it arrives at the beginning of the section.

This rail circuit system has been used in connection with an infinite variety of electric signals; that is, the local circuit with its battery *d*, has been used for turning single signals, double signals, signals for the protection of single tracks, for locking the levers of interlocking apparatus, locking draw-bridges, locking switches, moving automatic signals, ringing of bells for highway crossings, alarm bells for depots to announce the approach of trains, etc., etc.

The essential and important feature of this system is that the failure of the battery, or wire, or any interruption whatever of the current instantly causes the signals to be turned to danger.

Several of the important roads of the country have applied this automatic rail circuit in connection with semaphore signals, having laid a compressed air main along the track where the block signals are to be operated, the compressed air furnishing the motive-power for the operation of the semaphores. Two signals are arranged for each section, one "home" and one "distant" signal.

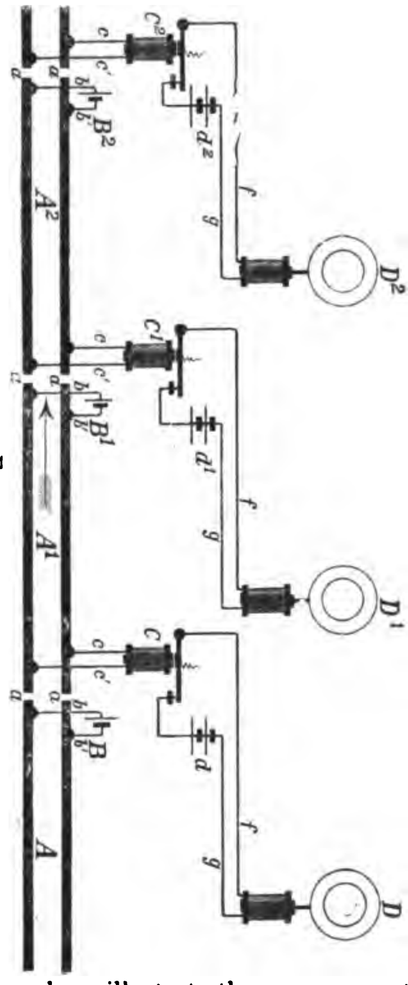


FIG. 10.

Figs. 11, 12 and *13*, illustrate the arrangement of signals.

In *Fig. 11*, a train is supposed to be on section *A*, and the two semaphore signals *R* and *G* stand to indicate "danger."

In *Fig. 12*, a train is supposed to have reached and passed on to

section A^1, turning the signals R^1 and G^1 to "danger," and at the same time turning signal R to "clear," leaving G at "danger," to indicate to an approaching train that the next section ahead is occupied by a train.

Fig. 13 shows a train on section A^2. Signals R and R^1 and G are "clear," G^1 remaining at "danger," to caution the engineer of the approaching train on section A^1 that section A^2 is occupied.

In the operation of these signals, if the engineer finds both signals clear, he can proceed at his usual rate of speed. If he finds G, G^1 or G^2 at "danger," he must be prepared to stop before arriving at the next signal post ahead, and he must not pass the next signal post ahead until one or both signals are clear. If one only is cleared, he must still proceed with caution and be prepared to stop before arriving at the next signal, in the event of both being at "danger."

METHOD OF CONTROLLING A HIGHWAY CROSSING BELL ON A SINGLE TRACK RAILROAD. SCOTT'S PATENT.

Figs. 14, 15, 16, 17 and *18* show the arrangement for giving an audible alarm of the approach of a train, at a highway crossing or other point on a single track railroad.

Fig. 14 shows the crossing A, and insulated sections R^1 and R^2, with the relay magnets c, d, connected to them, and the batteries a, a^1, for feeding the same, placed at the end of the sections farthest from the crossing.

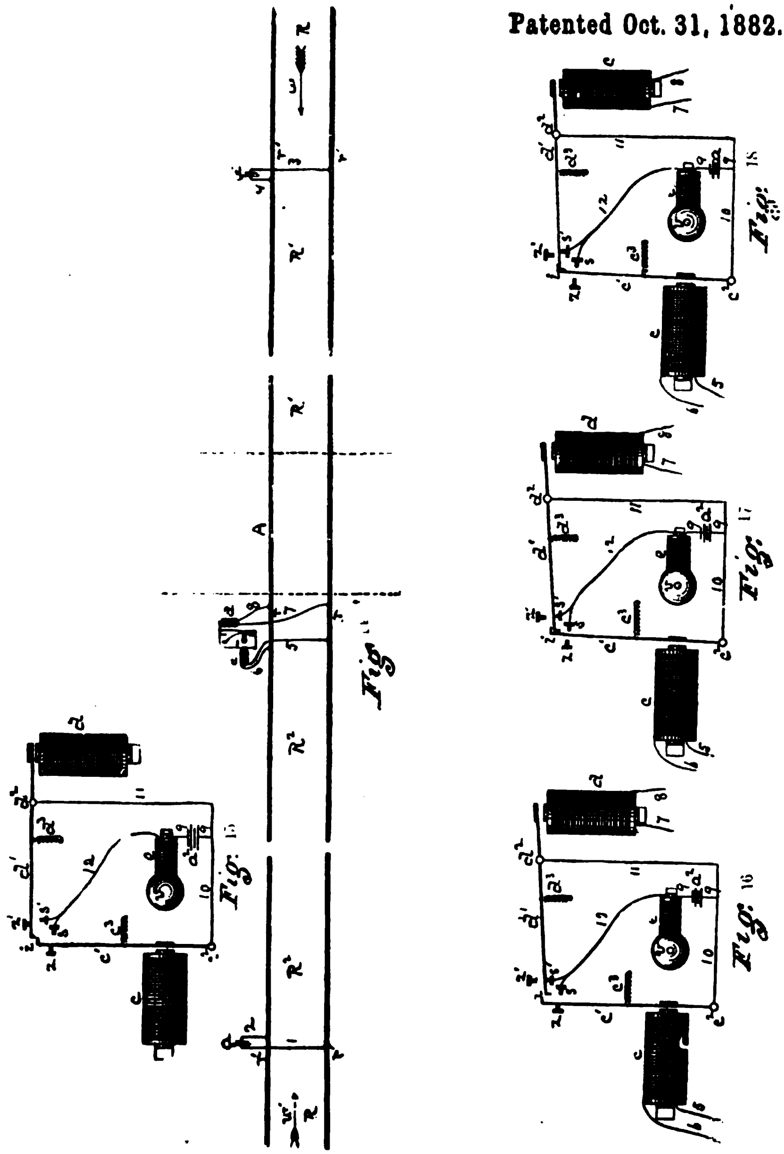
Fig. 15 shows the relay on an enlarged scale, and also the manner of connecting the local circuit with the continuous ringing bell v.

On a train approaching the crossing from the right, as indicated by the arrow w, the battery a^1 will be short circuited from magnet d, by the wheels of the train as soon as they have passed the insulations r^1, thereby demagnetizing magnet d, and its armature lever d^1, will assume the position shown in *Fig. 16*, closing the circuit of battery a^2 upon belt v, causing it to ring.

When the first wheels of the train have passed the insulations r, battery a, is short circuited, demagnetizing magnet c, and its armature lever c^1 will assume the position shown in *Fig. 17*.

When all the wheels have passed off of section R^1, battery a^1 will be restored to magnet d, magnetizing it and causing it to attract its armature.

Armature lever d^1, will then be in the position shown in *Fig. 18*, and the bell circuit will be broken as shown at s^1, and the bell will cease to ring.



The train passing from the insulated section R^2, battery a, is restored to magnet c, and the apparatus resumes the position shown in *Fig. 15*.

Should a train follow the first train, and pass insulations at battery a^1, before the first train has passed battery a, the magnet d, will again be demagnetized, and the bell circuit closed as shown in *Fig. 17*.

If a train approaches the crossing from the left, as indicated by the arrow w', exactly the same operations will take place, but in reverse order.

The HALL SYSTEM.

FUNDAMENTAL PRINCIPLES INVOLVED.

(1.) Automatic opening of an electric circuit, which holds a given signal at "safety" by the action of a passing train, the wheels of which operate a lever placed at right angles to the track. This lever raises a vertical spindle and thereby breaks the circuit in the track machine.

(2.) A gravity movement of a danger signal, when the circuit is broken.

(3.) The introduction of a relay into the circuit, by which the action of gravity will display a danger signal when the wires are either crossed or grounded.

(4.) The introduction of an interlocking device, by which a danger signal can only be set at "safety" by setting the next succeeding signal at "danger."

(5.) The introduction of a general interlocking system, by which an operator at a crossing station has the power to clear a given signal and at the same time loses the power to control all conflicting signals.

(6.) The introduction of suitable mechanism, by which a station agent has control over all signals.

(7.) The introduction of a suitable mechanism, by which the movement of a switch controls the movement of a signal.

(8.) The introduction of suitable mechanism, by which notification of the approaching trains may be given to station agents, to gate tenders, or to the general public.

PLATE I.

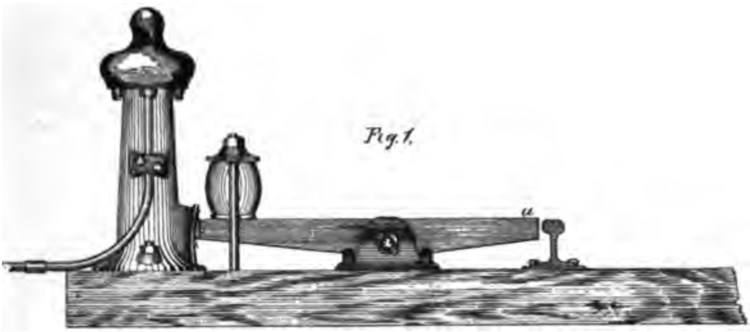


Fig. 1.

Track Machine

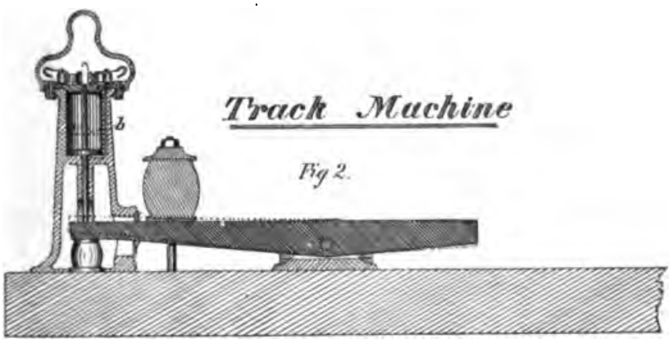


Fig 2.

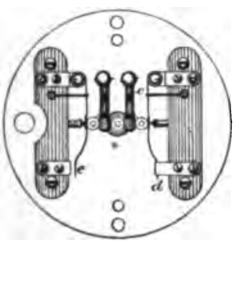


Fig. 3.

Fig. 4.

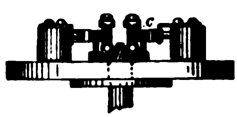
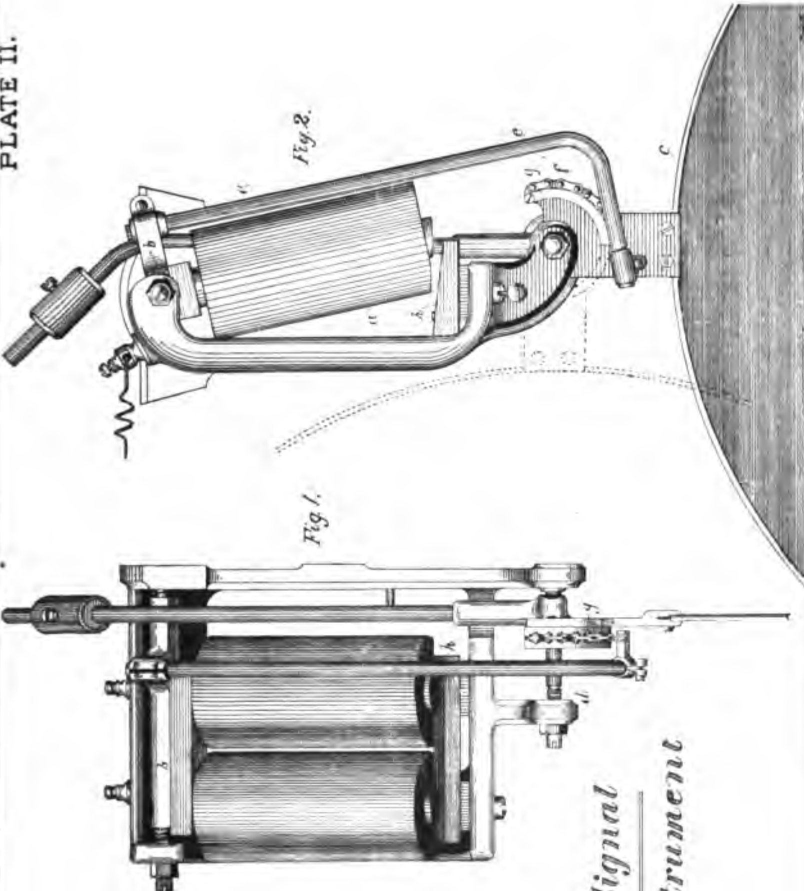


PLATE II.



Signal Instrument

PLATE III

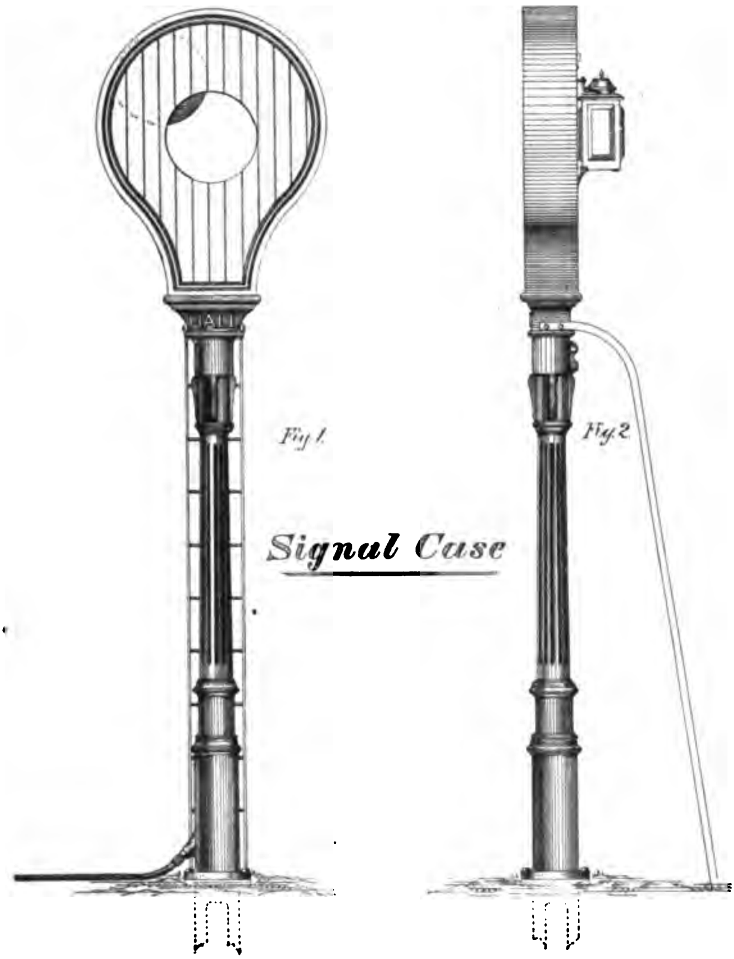


PLATE IV.

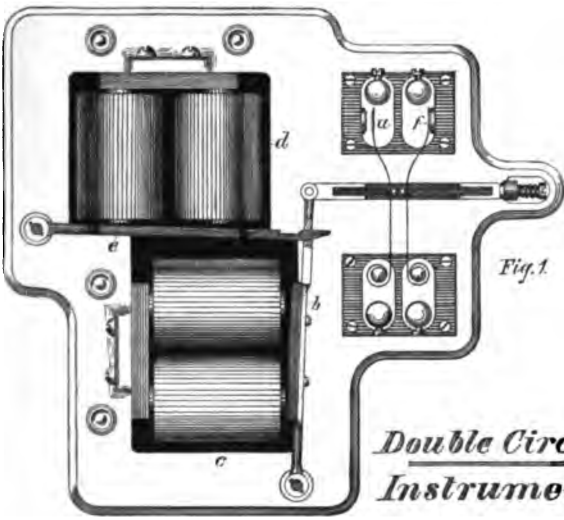
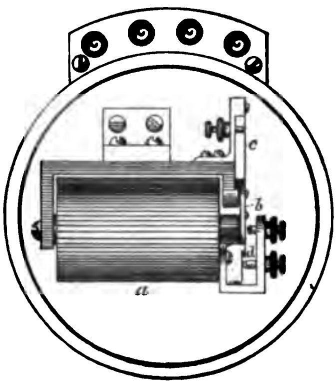


Fig. 1.

Fig. 2.

Double Circuit Instrument



Relay

Fig. 3.

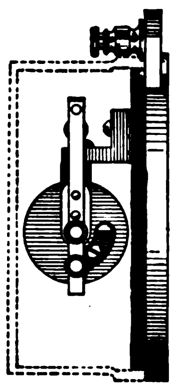
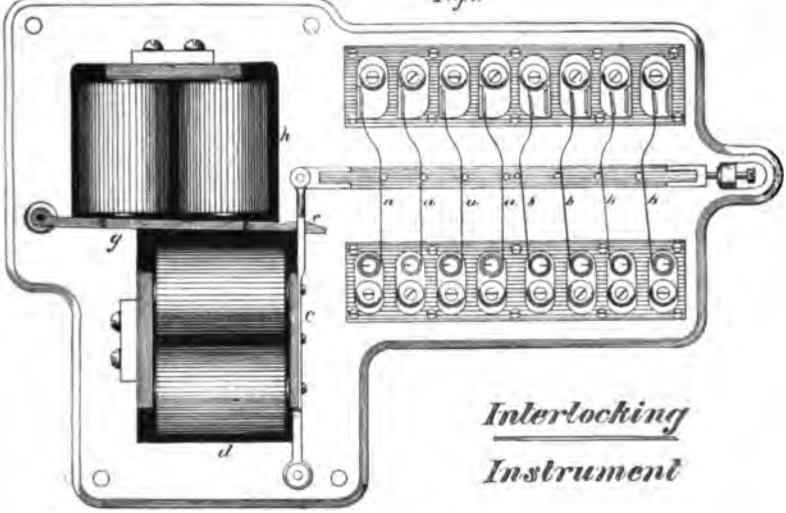


Fig. 4.

PLATE V.

Fig 1



Interlocking Instrument

Principle of Interlocking.

Fig 2

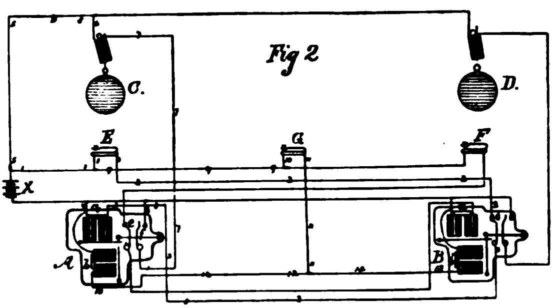
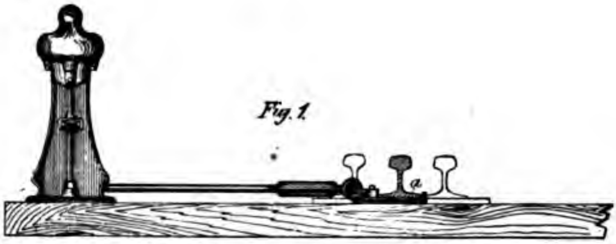


PLATE VI.

Fig. 1



Switch Machine

Fig. 2.

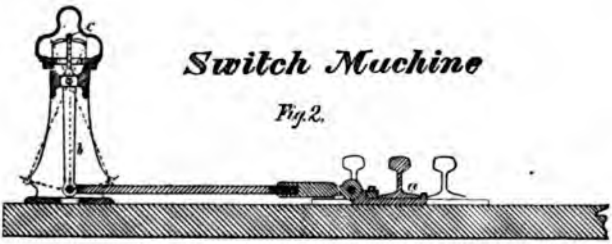
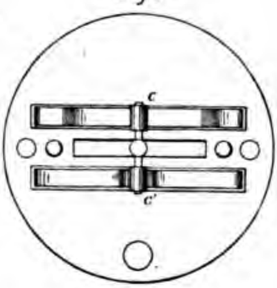


Fig. 3.



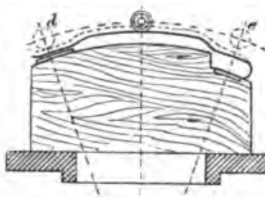


Fig. 4.

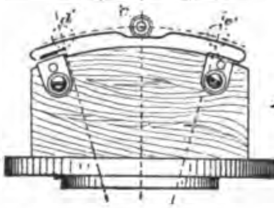


Fig. 5.

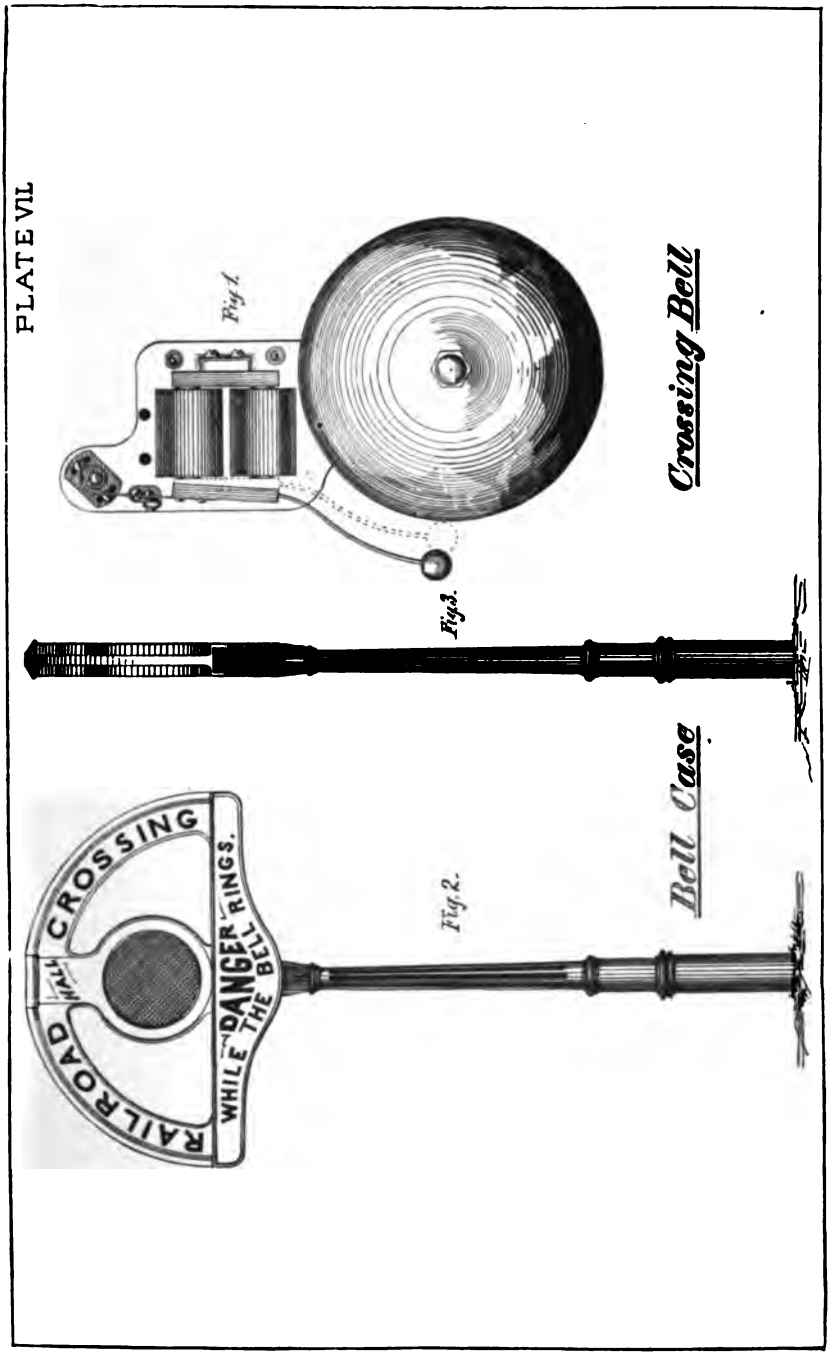


PLATE VII.
Fig. 1.
Fig. 2.
Fig. 3.
Crossing Bell.
Bell Case.
RAILROAD CROSSING
HALL
DANGER
WHILE THE BELL RINGS.

PLATE VIII.

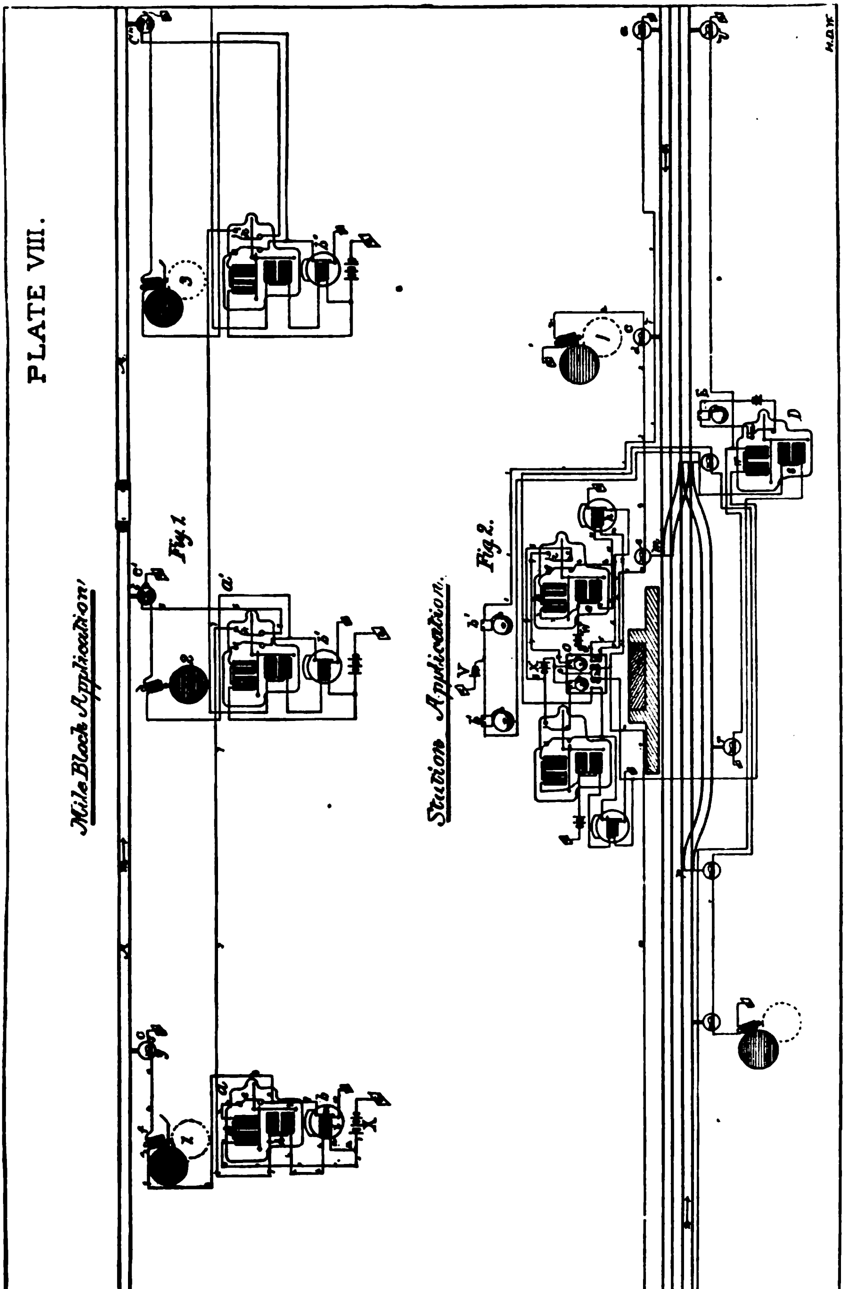
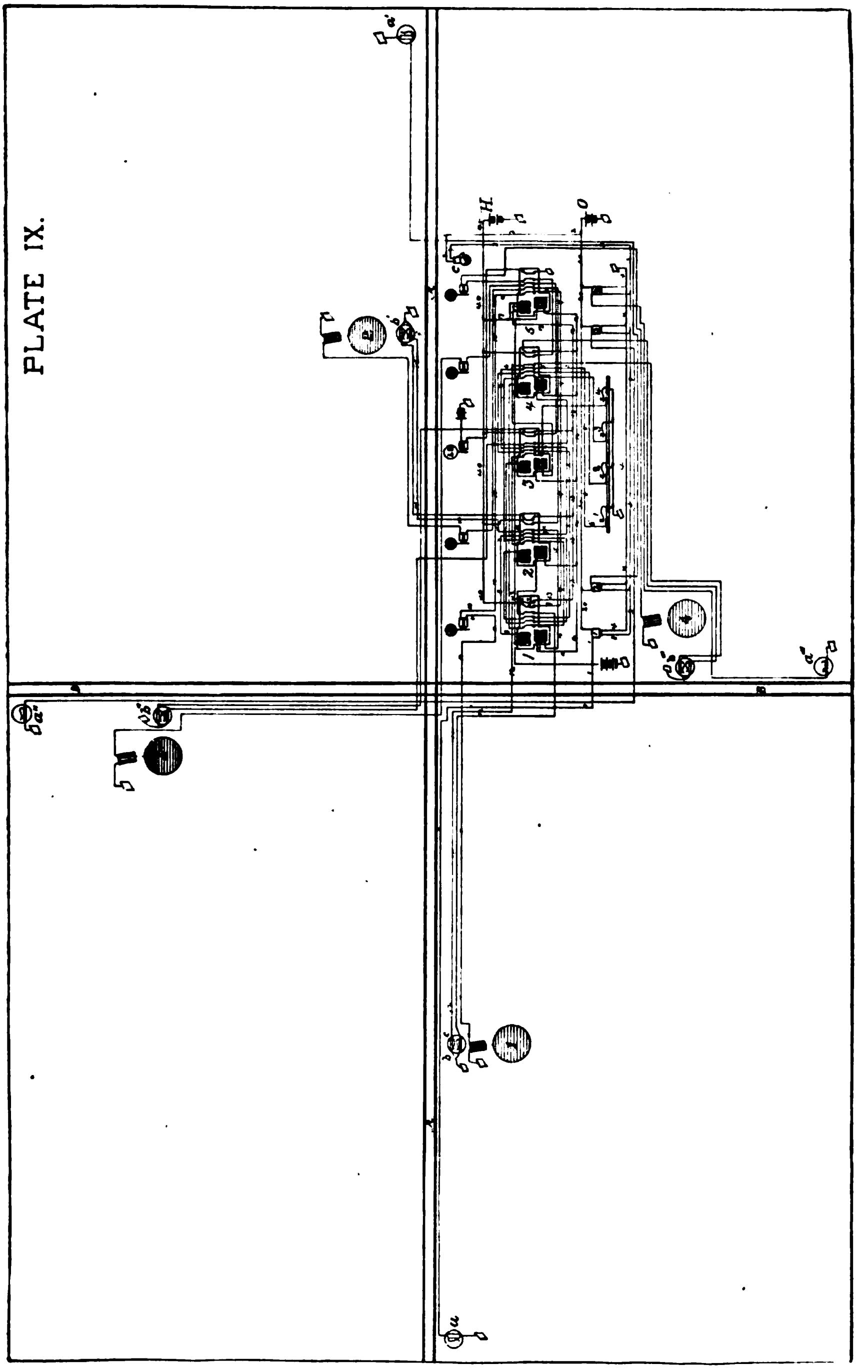


PLATE IX.



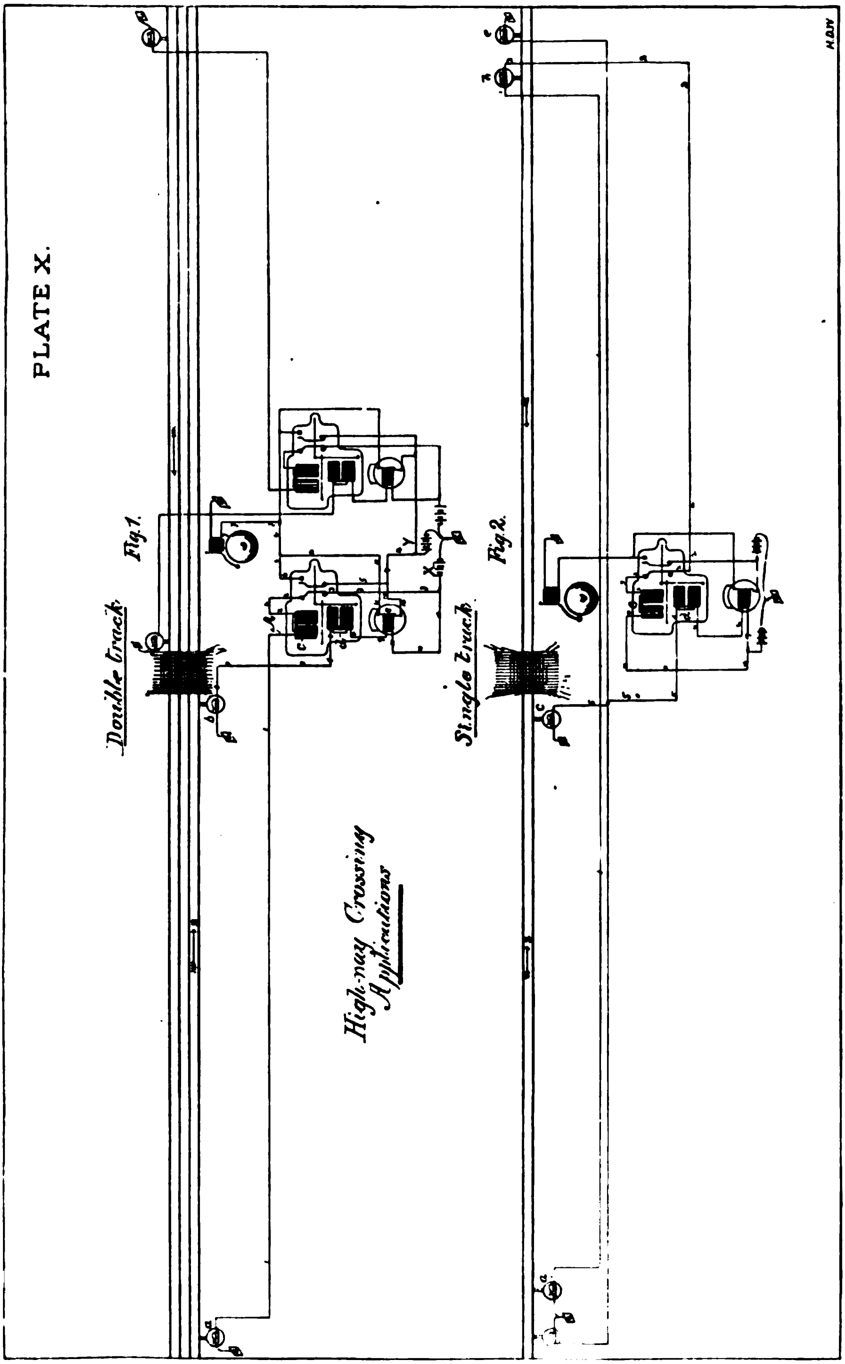


PLATE X.
Fig. 1.
Double track
Fig. 2.
Single track
High-way Crossing Applications

The methods by which the objects stated above are accomplished in this system, and the mechanism employed, will appear from the following description:

Plate I, Figs. 1, 2, 3 and *4* are views of the track machine, as placed at right angles to the track, used for the purpose of automatically opening an electric circuit, which holds a given signal at "safety;" by the action of the wheels of a passing train, which operate the lever at *a*, *Fig. 1*, causing a vertical piston, shown at *b*, *Fig. 2*, to be raised, so that it acts upon a lever *c*, *Figs. 3* and *4*, which breaks the circuit in the machine at *d*. A circuit may also be closed by this machine, by forming the circuit closer, as at *e*, *Fig. 3*, so that when the piston is raised by the lever, the circuit will be closed at *e*.

Plate II, *Fig. 1*, is a side view, and *Fig. 2*, a front view of the signal instrument, the gravity movement of which produces a danger signal, when the circuit is broken, referring to the drawing *a*, is an electro-magnet supported axially on a shaft *b*; *c* is a signal disc, supported axially on a shaft *d*, shown at *Fig. 1*; the two shafts are connected by means of a rod *e*, and chain *f*, the chain passing over the periphery of a sector of a circle, which forms part of the disc, as shown at *g*. The weight of the disc maintains the electro-magnet at an angle, as shown in *Fig. 2*.

The armature of the electro-magnet at *h*, is stationary; when a current of electricity is passing through the magnet, it is attracted to its armature, carrying with it the rod *e*, which turns the disc on its axis to a position at right angles to its normal condition, as shown by the dotted lines; as long as the current is maintained through the magnet, the signal will occupy this position, which indicates safety. When no current is passing through the magnet, the weight of the signal changes its position to the one indicating danger. This instrument is placed in a case, two views of which are shown in *Plate III*, *Figs. 1* and *2*.

Plate IV, *Fig. 1*, is a front, and *Fig. 2*, a side view of the double circuit instrument, which is introduced into the circuit for the purpose of continuing the action or effect produced momentarily in the track machine, and also by which the interlocking arrangement is accomplished whereby a danger signal cannot be set at "safety" unless the next succeeding signal is at "danger."

In the drawings, *a* represents a circuit closer, which is closed by

the attraction of the armature *b*, to its magnet, *c;* when this circuit has been closed it actuates magnet *d*, causing its armature, *e*, to be attracted, the act of which locks the first armature, *b*, thereby holding circuit closed at *a;* of course, if the circuit actuating magnet *d* is broken, the armature *b* will be unlocked, and the circuit will be broken at *a; f* is a circuit closer which acts directly opposite to *a;* that is, the closing of *a*, by means of armature *b* will open *b* and *f*, and when *a* is open, *f* will be closed.

Plate IV, Figs. 3 and *4*, are front and side views of the relay instrument, which is introduced into the circuit, and by means of which the signal will show danger when the wires are either crossed or grounded; *a* is an electro-magnet and its armature, *b*, is mounted upon an adjustable spring, *c*, the lower end of which forms a circuit closer; when the current is passing through the magnet, *a*, a secondary circuit, which is a shunt circuit, causes the main circuit to be shunted from the signal so long as the magnet is active.

Plate V, Fig. 1, is a front view of the interlocking instrument, *a, a, a, a* and *b, b, b, b* are circuit controlling springs, which are operated by means of armature *c;* that is, when armature *c* is attracted, the front contact springs *a, a, a, a* are closed and the back contact springs *b, b, b, b* are opened; when the armature has been so attracted it is locked by means of a detent, *e*, on armature *g*, and must so remain until the armature *g* has been attracted. This operation of course will withdraw the detent and cause the armature, *c*, to return to its normal condition, which opens the front and closes the back contact springs. Any desired number of springs can be used, as the case requires.

In *Plate VI*, are five figures representing the switch machine, by means of which the movement of the switch controls the signals. *Fig. 1* is a side view of the machine as placed at right angles to the track, and attached to the switch rail as shown at *a*. The movement of the switch rail from the main line of track, in either direction, would cause the lever *b*, shown in *Fig. 2*, to swing on its fulcrum, as indicated in the dotted lines. The short arm of the lever carries a small roller, *c*, which runs over a spring, as shown in *Figs. 4, 5*, and *6*. This spring has indentations so formed in it, that it will open or close as the roller passes over it, according to the form of the spring.

In this manner, circuits are automatically broken or closed by the movement of the switch, as the case may require. In *Fig. 4*, the switch being on the main line, the roller would stand in the centre of the spring, and thereby the circuit would remain closed, but if the switch was moved in either direction the spring would open, as shown at *d* and *e*. In the case of *Fig. 5* it is the reverse; the circuit is open when the switch is on the main line, and closed when moved in either direction from the main line.

By referring to *Plate VIII, Fig 2, O* represents a board upon which is placed two bells, two circuit breaking and two circuit closing keys. By means of these keys, the station agent may manipulate the signals as may be required. The operation of the bells give notification of the condition of the signals.

For the purpose of giving notifications to gatemen at crossings, and to the public waiting at stations, of the approach of trains, striking bells are used, which are operated automatically by the passage of the train at a given point distant from the station or crossing.

At highway crossings, where no gates are used, a large vibrating bell, shown in *Fig. 1, Plate VII*, is placed in a case, shown in *Plate VII, Figs. 2* and *3*, and erected at the crossing, so that when the train is approaching and when within one-half mile, more or less, from the crossing, the bell is automatically put in operation by the train, and continues to ring until the train passes the crossing. The remaining three plates consist of diagrams showing the application of the above described instruments. The general operation of the block signals will be understood by the explanation of *Fig. 1, Plate VIII. A, A* is a portion of track upon which trains run in the direction indicated by the arrow. This portion of track is divided into three sections, each of which is protected by a signal, as shown at Nos. 1, 2 and 3; a, a', a'' are double circuit instruments, b, b', b'' are relay instruments; c, c', c'' are track instruments, which are placed about 1,500 feet beyond the signals. The conditions of the signals when no trains are occupying the track, are at safety; they are maintained in this condition, as will be seen by tracing the circuit of No. 1 signal; commencing at battery *X*, the circuit runs by wire 1, through magnet *d*, wire 2, circuit closer *e*, wire 3, electro magnet *f*, wire 4, circuit breaker *g*, on track instrument *c*, wire 5, to the ground; this circuit being complete, the Signal No. 1 will

remain at "safety." The same circuit exists at each signal. When the train passes into the section protected by the signal, and operates the track instrument *c*, it will momentarily break the circuit above traced, and the signal will fall by gravitation to danger; at the same time the magnet *d* will be demagnetized, and its armature will release the armature of magnet *h*, causing the circuit to be permanently broken at *e*. This circuit can only be restored again by magnet *h*; when this magnet is vitalized, it will again close spring *e*, and the circuit through the signal will be complete, so that it will be set to safety. The restoration of this signal takes place after the train has passed into the section protected by Signal No. 2. In track instrument *c*, is a circuit *breaker* and a circuit *closer*, the circuit breaker is in circuit with Signal No. 2, exactly as described in No. 1. The circuit closer is in circuit with magnet *h*, on instrument *a*; it also includes magnet *i*, in relay *b*. By tracing the circuit, we find it runs from battery *x*, by wire 2, through magnet *i*, wire 6, magnet *h*, wire 7, spring *k*, wire 8, circuit closer *l*, on track instrument *c′*, to the ground. If the spring *k* is closed, the train operating track instrument *c′* will vitalize magnet *h* and *i*, on instrument *a* and *b*, which will restore spring *e*, and cause Signal No. 1 to be set at safety. So long as the train is operating track instrument *c′*, the circuit will be maintained so that *i* will shut the circuit from the signal, as follows: From battery *x*, through wire 1, magnet *d*, spring *e*, wire 9, circuit closer *m*, wire 10, to the ground. After the last wheels of the train have left the track instrument, the shunt circuit will be opened by the demagnetizing of magnet *i*, and the signal will be set to "safety." It will readily be seen that it is impossible to set Signal No. 1 to "safety" unless Signal No. 2 is at "danger," because so long as Signal No. 2 is at "safety," the back contact spring *k* will be open, and the restoring circuit running through it will be broken. If, from any cause, the wires should become crossed or grounded, the relay magnet would be actuated, shunting the circuit from the signal.

In *Fig. 2, Plate VIII*, is a station block application. The operation of which will be understood by the following explanation. As a train approaches the station towards Signal No. 1, the operation will be as follows: Upon reaching track instrument *a*, it will close a circuit through wire No. 1, bell *b*, to battery *V*, thereby operating the bell (which has been placed on the side of the station for

the purpose of giving notification to passengers); having reached track instrument *c*, it breaks the signal circuit, which runs as follows: From the ground through the magnet of Signal No. 1, wire 2, circuit breaker *d*, wire 3 (which passes through circuit breaker on switch instrument *e*), wire 4, circuit breaker *f* on station agent's board *O*, wire 5, wire 6, front contact spring *g*, magnet *h*, wire 7, to battery *W*. This causes the signal to fall to "danger," and the circuit will be permanently broken, as before described. The act of setting the signal to danger causes the back contact spring *i* to close, which completes a circuit from battery *x*, through wire 8, contact spring *i*, wire 9, and small bell, on station agent's board; causing the bell to ring as long as the signal is at "danger," thus notifying him at all times of the condition of the signal. The train, on passing track instrument *j*, completes a circuit through wire 10, relay magnet *k*, wire 11, magnet *l*, to battery *W*, and thereby restoring the signal circuit.

If the switch be misplaced, the signal circuit is broken, and cannot be restored as long as the switch remains open; in the same manner, the station agent can break the circuit by means of his key *f*, and as by *n* is a branch from the restoring circuit, he can restore the signal, provided the circuit has not been broken at any other point.

On the other side of the station, the arrangements of signals, circuits, etc., are similar to those already described, with the exception of the application for the side track, used for the purpose of shunting passenger and freight trains, which accomplishes the following operation: After a freight train has taken the siding and returned the switch *p*, to the main line, it closes a circuit, by means of track instrument *r*, which restores the signal to safety; as the passenger train approaches the station, it will, in addition to ringing the regular bell at the station, operate magnet *s*, in instrument *D* (as the circuit runs through the magnet on its way to the bell *b'*), the operation of this magnet will close spring *u*, which completes the circuit to small bell *E* (placed in close proximity to the switch).

This being an interlocking instrument, the spring will remain closed and the bell will continue to ring until the train passes track instrument *V*, when it restores the signal; the restoring circuit, running through magnet *w*, unlocks the spring and the bell circuit is broken; by this means the engineer of the freight train knows

that so long as the bell continues to ring, there is a train in the section; when the freight train leaves the siding, the danger signal is set by the opening of the switch, and it will be restored upon the train's leaving the section at *V*.

The operation of the interlocking will be understood by first referring to *Plate III*, *Fig. 2*. This figure represents the principle upon which the interlocking is based. *A* and *B* are interlocking instruments. *C* and *D* are their respective signal instruments, their normal condition being at "danger." *E* and *F* are circuit closers, corresponding to the signals, and by means of which they are operated. *G* is a circuit closer for restoring the signals to danger after they have been operated. With this arrangement in its normal condition, it is possible to operate either one of the signals by means of its corresponding key, but the act of operating one signal makes it utterly impossible for the operator to clear the other signal, until the first has been restored. This is accomplished in the following manner: The circuit from key *E* to operate signal *C*, runs as follows: From battery *x*, through wire No. 1, circuit closer *E*, wire 2, front contact spring on instrument *B*, wire 3, magnet *a*, wire 4, to the battery. The circuit from key *F* runs in the same manner through front contact spring on instrument *A*; therefore, if we close the circuit at *E*, we operate magnet *a*, which opens front contact spring *e*, on instrument *A*, and close back contact spring *f*; the closing of this spring completes a circuit from battery *x*, through wire 5, wire 6, signal magnet *c*, wire 7, spring *f*, wire 8, to the battery, causing signal *c* to raise to "safety;" it will now be seen that if we depress key *F*, the circuit will be broken at *e*, in instrument *A*, so that it will be impossible to affect the corresponding instrument. In the same way, if key *F* has been closed first, it breaks the circuit of key *E*. After a signal has been set or cleared, it can be restored at *g*; when this key is depressed, a circuit is completed from battery *x*, through wire 1, 9 and 10, 11, 12 and 13, to the restoring magnets *b* and b^1, which raise the springs. This principle can be largely extended by increasing the number of springs on the instruments. An example will be given of a practical application of the principle to the crossing of two single track roads at grade, shown in *Plate IX*.

A, *B* represent the two roads, crossing each other; in close proximity to the junction is a cabin, or tower, in which a case is

placed, containing the apparatus, by means of which the operator controls the movements of the trains. About one mile from the junction are placed track instruments, *a'*, *a''*, *a'''*, *a;* about one-half mile from the junction are placed signals, Nos. 1, 2, 3 and 4. The normal condition of which are at "danger;" in close proximity to them are track instruments, *b*, *b*, *b*, *b*. If, for example, a train is approaching the crossing towards Signal No. 1, reaching track instrument *a*, it closes a circuit through the wire No. 1, to a small indicator drop, through its magnet to wire 20, and thence to the battery, this causes the indicator to display a number, corresponding to the signal towards which the train is approaching, which in this case is No. 1. The dropping of this indicator closes as secondary circuit, which can be traced from battery *O*, through wire 2, small bell *c*, wire 3, indicator 1, wire 4, to the ground. The operator is thereby notified, by the bell, of the approach of a train, the indicator designating the track occupied by the train.

The operator must therefore clear Signal No. 1 to allow the incoming train to enter the protected section. He then depresses key No 1, closing a circuit through wire 5, front contact spring on interlocking instrument, No. 4, wire 6, spring on instrument No. 3, wire No. 7, spring on instrument No. 2, wire 8, to unlocking magnet on instrument No. 1, thereby unlocking the few front contact springs and closing the two back contact springs on that instrument. It will be discovered, by tracing the circuits from the remaining three keys, 2, 3 and 4, that they all run through the front contact spring on this instrument, before they go to the magnets on their respective instruments, consequently the unlocking of this instrument has cut away from the system these three keys, so that it is impossible to obtain any result from them, or to clear the Signals Nos. 2, 3 and 4, which operation, were it possible, would permit conflicting trains to have the right of way, the unlocking of this instrument closes the two front springs, the first of which closes a circuit from battery *P*, through wire No. 9, front contact spring in instrument No. 5, wire No. 10, through a miniature signal instrument (in the operator's case) wire No. 11 to Signal No. 1, thereby causing the signal to be set at safety. The miniature signal is used as a tell-tale to repeat, before the operator, the movements of the outside signal, and in this case shows him he has cleared the Signal No. 1. The train, upon reaching track instru-

ment *b*, closes a circuit through circuit closer *c*, which completes a circuit through wire No. 12, spring No. 2, in instrument No. 1 (which is now closed) wire No. 13, to the unlocking magnet on instrument No. 5. This opens the front contact springs and closes the back contact spring on this instrument, as the signal circuit ran through one of these front springs, it will, of course, now be broken so that the signal will drop to "danger," to protect the train in the rear. (It will be understood that the remaining keys cannot be operated.) The closing of the front spring in the the last instrument completes a circuit to a miniature signal marked *L B*, which indicates Line Blocked. Thus the operator is notified that the train is still in the section. Reaching track instrument *b'*, the train completes a circuit through spring *F*, wire 14, front spring on instrument No. 2, wire No. 15, locking magnet in instrument No. 1, wire No. 16, locking magnet in instrument No. 5, wire No. 17, to wire No. 40, thence to the battery, thus restoring the system to its normal condition, this being indicated to the operator by the return of the Line Blocked indicator to Line Clear, caused by the restoring of instrument No. 5, which breaks the circuit by the back spring. The same results are produced as trains approach on either of the other tracks.

A prominent feature of this interlocking arrangement is the cutting out of track instruments; that is, train operating track instrument *b*, has no effect on one of the circuit closers, the one that restores the system when a train comes from the opposite direction. In other words, a train uses only such circuits as are necessary to work its signals in one direction.

In *Plate X*, are two diagrams representing applications of a continuous ringing bell at highway crossings, one being a double and the other a single track arrangement.

In *Fig. 1*, a train approaching the crossing in the direction of the arrow No. 2 will break a circuit at track instrument *a*, which runs by wire No. 1 through magnet *C* on double circuit instrument *A*, front spring wire No. 3, to battery *x*, causing the front spring to open and back spring to close, the closing of which completes a circuit from battery *F*, through wires Nos. 4 and 5, back contact spring wires 6 and 7, through the bell, which continues to ring until the train reaches track instrument *b*, when it closes a circuit through wire 8, restoring magnet *d*, wire

No. 9; relay magnet, wire 10, to battery *x*, thereby restoring the double circuit instrument and stopping the operation of the bell. The introduction of the relay, in this case, causes the bell to ring if any of the wires are crossed or grounded; for instance, if wire No. 1 is grounded, the relay magnet will be actuated, closing the circuit from battery *x*, through wires 4 and 10, spring *e*, wires 11, 6 and 7, to the bell. The operation is precisely the same on the other track.

In *Fig. 2*, trains approaching in the direction of the arrow No. 2 break the circuit at track instrument *a*, which passes through wire No. 1, track instrument *b*, wire 2, front spring on double circuit instrument, magnet *C*, wire 4, to the battery, closing the bell circuit by means of back contact spring. Trains reaching track instrument *C* restore the instrument by closing the circuit through wire No. 5, restoring magnet *d*, wire 6, relay magnet and wire 7 to battery, thereby stopping the bell. The train, on reaching track instrument *b*, unlocks the instrument, but it is restored by track instrument *e*. The operation is the same in the opposite direction.

THE RAILWAY CAB ELECTRIC SIGNAL COMPANY.

DISTINCTIVE FEATURES.

(1.) The signal of danger is given audibly on the locomotive.

(2.) The signal continues to sound until interrupted by manual action.

(3.) The electric generator is movable, being a dynamo machine, carried on the locomotive, and actuating any portion of the road line, without local or fixed sources of electric current.

(4.) The advantage of a dynamo current in being free from the irregularities of batteries.

(5.) The use of a normally closed circuit, by means of the wheels of the locomotive, and the rail, to restrain the audible signal on the locomotive, and the interruption of such current on the rail to sound the signal.

(6.) The absence of force, or an open circuit producing the signal.

(7.) The small number of mechanical parts used, and the consequent minimum of original cost and repair.

The operation of the system will appear from the following diagrams and explanations:

The principle of this signal is as follows:

A locomotive is provided with an electric generator, or dynamo machine run by a small motor fed with steam from the boiler.

The two poles of the dynamo terminate by means of wires, one to the body of the locomotive, and one to the tender frame of the same, both having metallic contact with the rails by means of their wheels. These two points, or terminals formed by the wheels, must be insulated from one another; so that when on the rail, the wheels of the locomotive and the wheels of the tender are only connected together electrically by means of the rail. Where wood frames are used in tenders this insulation is already done; with iron frames the draw bar must be insulated.

We thus have a closed circuit in action by means of the dynamo, locomotive, tender, and the rail.

This closed circuit passes through a magnet in the cab which holds an armature to itself. When this circuit is interrupted, or opened, the armature leaves its magnet, and in so doing, by lever action, operates a bell, or whistle valve.

These signals continue to sound until the armature is returned by hand to its magnet, and held in place by the current. The interruption or opening of the circuit to cause the armature to leave its magnet, is made by insulating two abutting rails, one from another, so that when the locomotive wheel is on one rail, and the tender wheel on the abutting rail, the insulation between the rails will cause the circuit between the wheels to be interrupted or opened, when the consequent signal is given, by the armature leaving its magnet. The two parallel rails are insulated similarly, to cut the circuit for the wheels on both sides.

Thus an interrupted or opened circuit formed as described, gives an audible signal on the locomotive; this is the primary idea.

These signals are worked and controlled as follows:

From two insulated abutting rails, separate wires are led, to join which would destroy their insulated condition.

These wires are led any given distance for any signal purpose,

terminating at a switch—a draw-bridge—a station—at block points —or any other point from which a locomotive may be signaled, or which a locomotive may signal. By suitable parts controlled by magnets, so as to contact, and not to contact, these wires are opened and closed—as the case may be—at the points where they terminate.

If a switch is closed, the wires are closed; if a switch is open, the wires are open. Then when the insulated rail joints at the wires interrupt—as before shown—the current through the rail from the locomotive to the tender, such current must follow the wires leading from the two rails. Thus fundamentally, if the two wires are closed at any remote signaling point, the locomotive circuit will remain closed when passing the insulated joint where these wires join the rail. If the two wires are open at any remote signaling point, the locomotive circuit in the same position will be opened, the armature must leave its magnet, and the signal be sounded on the locomotive, while passing over the insulated joints.

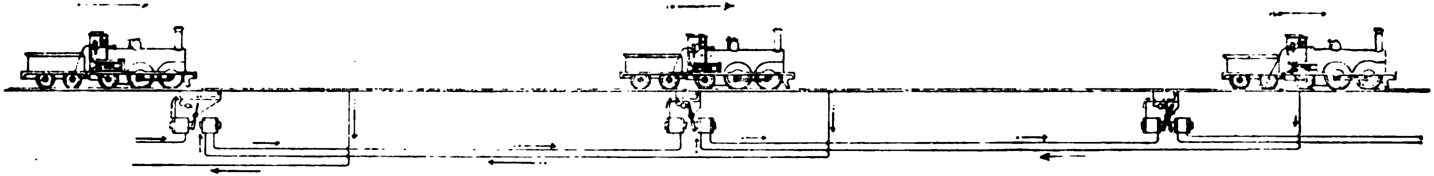
Thus a switch, bridge, station, block, or any point, "danger" means open circuit, and signal to locomotive, while "safety" means closed circuit, and no signal.

Thus a locomotive in motion forms a moving closed circuit on the rail, which is continued closed, or it is opened, as there may be safety or danger in its path.

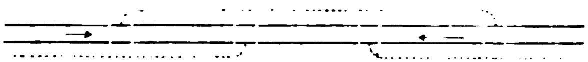
EXPLANATION OF DIAGRAMS.—(*See Plate XI.*)

In the double track block sketch, three locomotives are shown in three different modes of action—the locomotives being a mile or more apart. All the locomotives show the circuit from the dynamo machine on them, terminating in the wheels of the locomotive and the tender. The rail plan shows insulated rail points to actuate the relay magnets, and similar points to receive danger alarm signals—the first being always in advance of the second. The circuits are the same for each block space, and are marked similar to the locomotives.

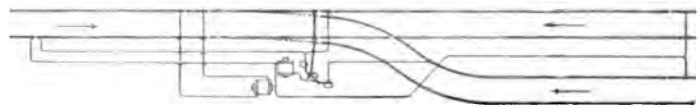
—— Locomotive - ——— } has formed a circuit of similar mark, over an insulated rail joint at a relay actuating point, actuating the near relay magnet in its circuit, to separate the contact points of the relay, and thus indicate at its danger alarm



Plan of Double Track Block Signal Sections

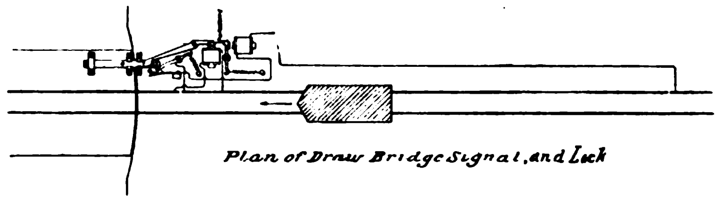


Arrangement of Single Track Block Signal Sections

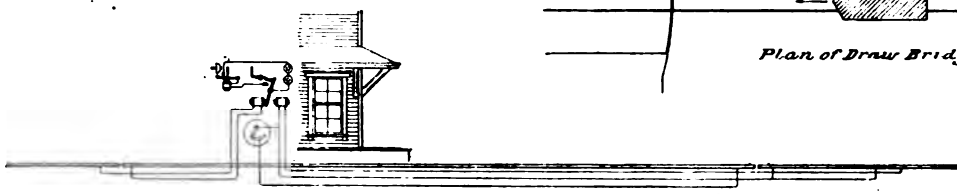


Plan of Switch Signal, 3 Points

Plan of a Block Signal Section for Single Track



Plan of Draw Bridge Signal, and Lock



Plan of Signal to Engine from Depot, and Signalling Depot

Railway Cab Electric Signal Co.'s System.

rail point, and has also actuated (on the same circuit) the magnet of the remote relay, to close the contact points, and thus set it at "safety," at its danger alarm rail point.

—— Locomotive - - ——— } is over the insulated joint of a danger alarm point, set at "safety" (or the points in contact) by locomotive - ——— }, as just described, and there being a path for the circuit from the wheels of locomotive - - ——— } by the rails and wires through the points in contact, no signal is received on such locomotives, the mile ahead being at "safety" for its advance.

—— Locomotive - - - ——— } is approaching an insulated joint of a danger alarm rail point, where the contact points of the relay have not yet been set together, or at "safety" by the circuit and locomotive - - ——— }, so locomotive - - - ——— } will be signaled when over that point, as the circuit from the rail through the contact points will be broken, there being then no path for it from wheel to wheel.

The wire connections all set the near relay magnet at "danger," and the remote relay magnet at "safety." That is opening the contact points at the near relay and closing them at the remote relay.

The plan of a single track block section shows how the circuits are made, so that a locomotive entering at either end, sets both before and behind at "danger," and in leaving the block sets both these points to "safety." In the sketch, the points are shown in contact, or at "safety," and dotted lines show the circuits to the alarm danger points on the rail. There being, as in double track sketch, relay actuating rail points, and alarm danger rail points.

The arrangement of single track block stations, shown by the sketch above, the last one exhibits how the section circuits are arranged to lap each other in series of threes; so that in no case can two locomotives be within a given distance, without receiving an alarm signal at an alarm danger rail point, which has been set at danger at a relay actuating rail point.

The switch signal sketch shows the points in contact (or circuit closed for safety) for the main line, and open for danger for the siding. If the switch was turned for the siding, it would close that circuit, and open one for the two points on the main line. The circuit through the magnet is to lock, or ring a bell at the switch. This can only be done when the switch is at "safety" to the line of

rail in use. When it is not so placed, there can be no circuit through the magnet, and the locomotive is signaled at the rail point where the wires terminate. The other circuit and magnet unlock the switch, or stop the bell, in passing.

The Draw-Bridge Signal shows a bridge bolted, and the bolt locked. By lifting the locking lever and pulling the bolt, the two contact points held together by the bolt separate, and the locomotive at the remote insulated danger alarm rail point would find no circuit, and would receive a signal. When the bridge is bolted, the two contact points are brought together, and the circuit can then pass from the remote danger alarm rail point to the magnet to lock the bolt. The other circuit and magnet are to unlock the bolt in passing.

The Depot Signal shows at the point farthest from depot, a circuit from the rail to shunt on a local current to ring a bell at the depot. The nearer rail point circuit runs to an electric switch in the depot, whereby the circuit can be opened or closed. By such switch, the locomotive can be signaled or not, by this means, at the rail point where the circuit or wires terminate. The circuit shown from the rail point when past the depot, stops the bell at the depot which the approaching locomotive had actuated.

As a preliminary to critical examination of the operation of these signals upon the railroads where they are in actual operation, the writer obtained from three gentlemen, who had had large practical experience in the use of signals of various kinds, a statement of what each would consider cardinal requirements in an ideal system of signals. Of the gentlemen who kindly responded to my inquiry in this direction, Mr. Chamberlain, the Superintendent of the Providence and Worcester Road, was the first to make a systematic study of the signals employed upon any road and to place before the public a clear and succinct tabular view of the work done under the system in use and of the number of failures from the various causes which rendered the system inoperative within a given period of time.

Mr. McCrea, the General Manager of the Pittsburg, Cincinnati and St. Louis Railway Company, is well known as a zealous advocate of every precaution which can add to the safety and efficiency of railway service.

Mr. Blodgett, in his capacity as electrician of the Boston and

Albany Railroad, has had wide experience both in the theory and the application of electricity to the problem under consideration.

The following are the communications sent in answer to my inquiry :

PROVIDENCE AND WORCESTER RAILROAD COMPANY.
SUPERINTENDENT'S OFFICE.

PROVIDENCE, R. I., January 9, 1885.

PROF. WM. A. ROGERS, *Harvard College Observatory, Cambridge, Mass.*

Dear Sir:—In compliance with your request, and as per my promise, I would suggest the following questions relative to the systems of electric signals on the different railroad lines:

(1.) By what system are your signals operated? Is it by open or closed circuit?

(2.) Is the normal condition, *danger*, when any accident occurs to the mechanism of the signal or any part of the apparatus?

(3.) Does your system show *danger* immediately upon a train entering the block protected by signals?

(4.) Will signal remain at *danger* in case a train breaks apart in one or more places, and will it remain at *danger* in case the first section or engine has passed out of the block and entered the section or block ahead?

(5.) Will signal show *danger* in case of a broken rail, or an obstruction by rails being placed across the track?

(6.) In case switches are set wrong, or are being used within a block, will the signal which protects that block show *danger*? If so, can you fully rely on it to protect you from a rear collision?

(7.) Will your system show *danger* when a car is left on a side track, in such position as to obstruct the main track?

(8.) Will your system of automatic signals, under any conditions, show *safety* when *danger* should be shown?

If so, under what conditions?

(9.) Can your system of signaling be operated from any point desired, by hand, as effectually as by train while in section?

(10.) Is the apparatus employed entirely free from atmospheric influences?

(11.) Is your system arranged so that all the switches in block can be electrically locked and not unlocked during the time that the block is obstructed by a train or otherwise?

(12.) Does your system permit the over-lapping of one or more signals, so that one or more signals will remain at *danger* until the whole train has passed from the block and over part, or the whole, of the next block?

(13.) In case one railroad crosses another at grade, or at a junction, or a branch road diverges from the main track, can your signals be so arranged that they will block out (by home or distance signals) trains in either direction, which are opposed to the safety of any train using main track, or vice-versa?

(14.) Will such signals work automatically from all switches, and work by hand from switch-houses or otherwise?

I think the above interrogations cover the important points in the matter of signals.

In relation to the interlocking system of switches, I am not prepared to make any statement, as we have no equipment of the same on this road, and I have not had the opportunity to make such a thorough investigation as would warrant a positive opinion as to their merits.

I shall be pleased at any time to give you any information desired, if in my power, and hope the questions propounded herewith will meet your approbation.

Yours, very respectfully,

W. E. CHAMBERLAIN,
Superintendent.

[COMMUNICATION FROM MANAGER McCREA.]

The requirements of an Automatic Electric Block Signal System, are briefly:

(1.) That the system should be reliable beyond question, so that in case of rouble, the responsibility can readily be placed.

(2.) The signals should indicate either "stop" or "go ahead;" never cautionary, unless as a distant, indicative of a Home Signal in advance.

(3.) The signal in its "clear" position should indicate an entirely unobstructed track, and should hold all conflicting signals to "danger," and ock all switches (if possible, in the position to act as throw-offs), which, by being moved during the passage of a train running according to a signal, might either throw it from the track, divert it from the intended course or allow another train moving in either direction, to collide with it.

(4.) Semaphores should be used to govern running tracks. On roads which run to the right, the arm should point to the right of the direction in which the train is moving, and on roads which run to the left, the reverse should be the case—this for the purpose that direction may be indicated. It is not, in all cases, possible to place the signals for the same direction, on the same side of the track, consequently a disc signal, even if shielded on the back, cannot (unless by rule, or of a distinguishing form, neither of which is hardly to be considered good practice) be made to indicate direction.

(5.) Pot Signals should be made to govern sidings, in order that as few signals as possible be displayed on the main running tracks, and again, that a short sight only be given, so as to compel an engineman, while on any subordinate track, to keep his train under complete control.

(6.) The current should hold the signal to "safety," so that in case of failure of the battery, the signal would automatically indicate danger.

(7.) On a single track the Block Section should so over-lap, that no two trains moving at speed in opposite directions, should be allowed in adjoining sections, to approach each other at the same time.

(8.) Provision should be made to indicate the position of all signals in adjacent Block Sections, to the train order or telegraph office.

(9.) Atmospheric disturbances should be provided for, so that in no case could an electric charge hold a signal at "safety."

Yours very truly,

JAMES MCCREA,
General Manager.

[COMMUNICATION FROM MR. BLODGETT.]

PROF. WM. A. ROGERS, *Chairman Committee on Railroad Signals*, FRANKLIN INSTITUTE *Exhibition, etc., Philadelphia.*

My Dear Sir:—In response to your kind invitation some time ago to give you at convenience my views of what an ideal railroad block signal should be and do, I submit them herewith, simply stating, by way of preface, that I have made no attempt to discuss the question broadly, or the merits of any particular system; but merely to outline the subject, and offer some general suggestions. I am committed to no system of signals farther than warranted by its conformity to the principles here laid down, and I try to deal with all in fairness, from the standpoint of one who would recognize the merits and point out the defects of each, rather as a stimulus to further development than as a cause for discouragement.

Interlocking apparatus, whereby the positions of switches and signals relating to a particular piece of track, are so dependent on each other that the signal for a train to proceed in a proposed direction cannot be given until that route has been made complete, while during the existence of such signal, no signal can be given for a train to pass over any conflicting route, has been, in my opinion, brought much nearer practical perfection than line block signals, so-called.

Interlocking is in use in this country to a limited extent at junctions, grade crossings of railroads, and in yards where the movements of trains over the same tracks in the same or opposite directions are very frequent.

By far the greater number of such devices which have been invented simply warn the engineer visibly or audibly of danger potential or actual, but would not prevent a disaster should he disregard the warning, or lose control of his train. A few systems provide that contact with some part of the apparatus shall forcibly remind the engineer of his neglect, and in one or two inventions it is impossible for him even to reach the danger point.

In the best systems of interlocking where the mechanical interdependence of switches and signals has been made as perfect as human wisdom has yet discovered how to do it, and supplemented by electric appliances dependent on the movements of the trains, an accident would seem well-nigh impossible.

The application of block signals to a line of railroad is commonly made by dividing it into longer or shorter sections, according to circumstances, each of which is provided with one or more signals designed to show to a train

whether or not it may proceed over the portion of the track to which the signal belongs. Of all the accidents which may happen to railroad trains, I think there are but two against which we can reasonably expect block signals will provide, viz.: the presence of another train in dangerous proximity, and a broken or displaced track.

Recognizing that these two are by far the most fruitful sources of accident, many inventions have been made which professed to furnish complete protection against them, but thus far with only partial success. At first mechanical devices were used, operated by some person designated for the purpose. This is, to a large extent, still the case. They are, however, always open to the following grave defects: (1) the signal man's perception of danger may be wrong, (2) his judgment may be defective, (3) the mechanical appliances he controls may work imperfectly and lure a train into the danger they were designed to guard against. Appalling disasters have been caused by each of these, which we afterwards saw might have been easily prevented.

Experience has demonstrated that whenever mechanical principles can be substituted for human perception or judgment, a very great increase in certainty and safety is the result.

This fact has been gradually more and more recognized by those who have to do with railroad signaling, and many attempts have been made to invent a system which should be as far as possible independent of perception or judgment in their operation, and be governed partially or wholly by the movements of the trains or the condition of the track (whether occupied or unoccupied) or both.

The problem simply stated is this: Given the complicated and varying train movements over a railroad, to devise means whereby each of these movements which can imperil any other train, shall be signaled to such train in ample time to allow effective measures for its safety to be taken; also that any displacement or interruption of the track over which a train is to pass shall be at once made manifest, and that each of these shall be done with certainty and regularity by the apparatus itself; that is, it shall be *automatic*.

I must here, however, frankly say that no device I have ever seen perfectly fulfils these requirements, and some do not even profess to do so. Others make the pretence, but when put to the test, prove unreliable. It would seem at first sight as though there might be an indefinite number of such devices, differing from each other only in details of construction or operation, moved by clock-work and a weight or spring, by compressed air or wind-power, by a running stream or hydrostatic pressure, by the electric current or the attraction of a magnet, or by a combination of two or more of these principles, but practically we are confined to quite a narrow range. For instance, the condition that a signal shall show the occupancy of a section by a train can only be completely met by an instrument which shall continue to show danger as long as any portion of a train, even a single pair of wheels remains in the section, or in dangerous proximity thereto, and shall at once indicate this, no matter how the obstruction came there.

Again, the requirement that a signal shall show whether or not the track is continuous through the whole of the portion the signal governs, seems to me

to positively exclude all such systems as operate by track or hand instruments, and can be set to "danger" or the reverse only at a few detached points in the section. I know of but one method by which this requirement can be met, viz: by an electric current through the rails, the breakage or displacement of any one of which shall prevent its passage. This can be done potentially by an open circuit, which is completed for the current to pass at the moment when we wish, or actually by a closed circuit through which there is a continual flow of electricity. The latter is, therefore, preferable, though at a somewhat greater cost of maintenance. In either case, the display of a danger signal, or the reverse, should depend on the occupancy and continuity of the track, and not on the previous operation of some other part of the system.

An ideal railroad signal would combine the good points of all those which have yet appeared. These seem to be the requirements of such a system, as developed by past experience.

At junctions, crossings, draw-bridges and other dangerous or complicated places, interlocking apparatus will be used, so connected that the passage of trains over conflicting routes at the same time is *mechanically impossible*; this will be further made sure by the use of electric currents controlling and limiting the signal man's operations to such as are perfectly safe and proper, and to indicate to him the movements of trains.

"The offer of a right of way and its acceptance by a train, should prevent interference in any way with its passage in safety, unless the right of way is voluntarily relinquished, when it may be given to another train. *It should, however, always be in the power of the signal-man to put a signal instantly to danger and stop a train* to which he may have given a right of way, whenever any contingency arises which makes that desirable. No mechanical or electric device should ever be so attached to interlocking apparatus as to lock a signal in an "all clear" position, but the locking should take effect on the first movements of all conflicting routes."

In line block signals, I think the following principles should be observed:

The signal should be, as far as possible, *automatic*. It must be prompt, positive and efficient in action. The information conveyed by it must be instantly and perfectly intelligible; there must be no delay or ambiguity in interpreting its meaning. It should, therefore, show three things, and only these: (1) That the track over which the train is to proceed is continuous and unoccupied through the whole length to which the signal applies; (2) that it is *not* continuous or is occupied; (3) that the signal is itself out of order and must not be depended on.

Much of the value of a signal will be due to the kind, form, position, color and size of the instrument, and these will commonly vary somewhat with circumstances, but should be as uniform as possible. A visible signal can usually be seen farther than an audible one can be heard. The form, position and size should be such that the signal will be plainly visible from the first moment when its indication could be of service; also such that it cannot be confounded with something else in the same vicinity. The semaphore arm has probably given better results than any other form of signal.

The color of a signal should be in marked contrast to the back-ground against which it is to be seen, and if more than one color is used there should be as much difference between them as possible.

When practicable, the indication of the signal should be readily perceived by *both* the color and position, which ought to be different for each different indication, but signals for the same purpose should invariably mean the same thing along the entire line of road.

However complicated its functions may be, a signal should be mechanically a simple machine, of few parts, not liable to derangement, easily put in order when necessary, and of great durability. It should also be entirely independent of weather or other atmospheric influences. Finally, it should be cheap enough in first cost and in maintenance to make its use depend entirely on its merit, and not at all on the question of expense.

The use of any such device ought to be as an addition to, and never as a substitute for, the utmost care and watchfulness human forethought can take. I am, sir, with great respect, very truly yours,

GEO. W. BLODGETT,
Assistant Engineer, Boston and Albany R. R.

Boston, July 11, 1885.

It would be too much to expect that either of the systems under consideration should perfectly meet the demands of an ideal system so clearly defined in the preceding communications. Many improvements, resulting from experience, have been made since electric railway signals were first introduced, and minor improvements will doubtless continue to be made, but it will be seen from the data given below that the systems in operation are now so nearly perfect that their use in the daily operations of a road is no longer an experiment. The old Hall system, the first to be introduced in this country involved the use of an open circuit. It was only by the expenditure of many thousands of dollars and as the result of a multitude of experiments that it was demonstrated that the conditions of the problem require a closed circuit. It is to be noted in this connection that the exhibit of the Wharton Switch and Signal Company relates to the new Hall system, in which the closed is substituted for the open circuit.

This gradual improvement both in the application of fundamental principles and in the perfection of mechanical details, is well illustrated in the changes which have been made in the form of the relay, used by the Union Switch and Signal Company.

The following illustrations and description relate to the instrument known as the Westinghouse patent

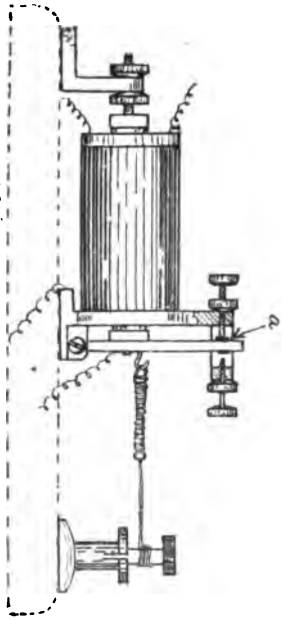


Fig 19

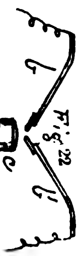


Fig 22

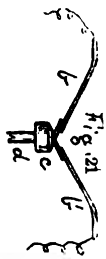


Fig 21

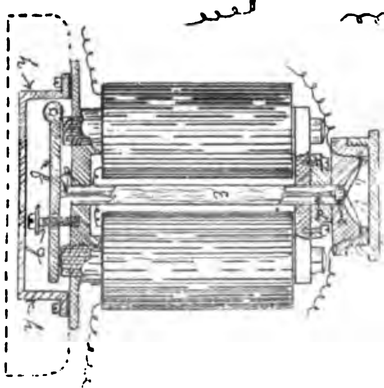


Fig 20

Fig. 19 shows the style of relay, formerly used in connection with these signals, and *Fig. 20* shows the improved style now used.

By reference to *Fig. 19*, it will be seen that this is the style of relay used in telegraphy, and its contact or local circuit closing point *a* is very small and exposed to the atmosphere, and is liable to become covered with dust in such a way as to keep the local circuit broken when the armature is attracted.

The means of adjustment on this relay are too easy of access, and they are liable to be interfered with in such a way as to cause the apparatus to work improperly.

Referring to *Fig. 20*, it will be seen that the contact springs *b*, *b'*, which are closed or pressed together by the head *c* of the rod *d*, are fastened to a hard rubber block and covered by a brass cap, which is screwed down over them, thereby enclosing them in a dust-proof case.

The rod *d* passes down to the tube *e*, and rests upon the armature *f*, moving down with the armature when it is released, thereby allowing the springs *b*, *b'* to separate and break the local circuit, and raising again with the armature when it is attracted by the magnet, and presses the springs together again, closing the local circuit. The screw *g* controls the drop of the armature and is the only adjustment used in this form of relay.

The cap *h* is fastened on to the base of the instrument by small screws and encloses the armature *f*, screw *g*, and lower end of the rod *d*, in a dust-proof chamber.

Fig. 21 is an enlarged sketch of the contacts and shows the local circuit closed.

Fig. 22 is the same, showing local circuit broken. It will be seen that when the springs *b*, *b'* are pressed together by the head *c*, there is a good contact at the end of the springs, and also through the head *c*.

In estimating the commercial and the practical value of any system of signals, three facts must be taken into consideration:

(1.) It is to be considered chiefly as an AID in preventing accidents, by compelling caution on the part of the employés of a road.

(2.) Even if the signals fail to operate, even if a safety signal is shown when a danger signal should be displayed, this failure does not introduce any additional element of danger, over that which would exist if there were no such system of signals in use.

(3.) The whole question of the use of automatic signals in any case resolves itself into a question of railroad economy. The cost of maintenance would not probably be a very serious matter in any event, but no road could endure the delay and interruption caused by the frequent display of false danger signals. It is obvious, therefore, that the mechanism of any system on trial must be so perfect that the number of failures shall not be sufficient to cause appreciable delay in the running of trains.

A limited personal examination of the operation of any system could not in any event count for much as a test of its merits. Still it was thought desirable to make this inspection. The writer, through the courtesy of Superintendent John Adams, of the Fitchburg Road, passed over that part of the line on which the signals are located, several times on different engines. In no case was there a failure in the operation of the signals.

President Watrous, of the New York and New Haven Road, kindly furnished a pass for a trip on any engine over that road for the purpose of witnessing the operation of the Hall Signal. A very interesting and satisfactory trip was made on the fast night express.

By the courtesy of Thos. C. Miles, General Manager of the Railway Cab Electric Signal Company, an engine was placed at the disposal of the writer for an examination of the system represented by this company at the station on the Staten Island Railroad, at which all the preliminary experiments on this system were made. This examination was entirely satisfactory. All the tests made, indicated a high degree of certainty in the operation of the signals.

Investigation of the Performance of the Signals upon the Roads upon which they are in use.

THE SIGNALS OF THE UNION SWITCH AND SIGNAL COMPANY.

The signals of this company are in use upon all the roads running out of Boston, except one. The Fitchburg Road was the first to adopt the system, in 1880. At present, the number of trains operated daily by twenty-seven signals is 152, of which 114 are regular and 38 are irregular. Every engineer is instructed to fill out a blank, of the following form, whenever a signal indicates danger from any cause. This report of the engineer, however, indicates only the probable cause, as apparent at first sight, of the danger signal. This report is returned to the office upon his arrival at Boston. With this report as a general guide, a signalman is sent to investigate the real cause, and his return is made upon the stub blanks. For the first two or three years, the maintenance of the signals was in the hands of the signal company, but during the past two years the railroad company has had their care in charge.

[*Form of Blank.*]

FITCHBURG RAILROAD.

ELECTRIC SIGNAL REPORT.

188

MR. JOHN ADAMS, *Gen'l Superintendent.*

Dear Sir:

Outward train No.
Inward train No.
Extra train No.

at about o'clock, M. found Signal No. at DANGER.

I report the cause (if ascertained) by writing *yes* opposite the proper question below:

Was Train in Section
Was Hand Car or Truck in Section
Was Rail Broken in Section
Was Track being Repaired
Was Switch open in Section
Was Switch unlocked in Section
Was Cause unknown

(If the danger signal was found at SAFETY and did not turn to DANGER as it should, write "yes" here)

Engineman.

THE UNION SWITCH AND SIGNAL COMPANY.

Gentlemen:—Will you please investigate the above report, and advise me what caused the signal to remain as stated.

Yours truly,
JOHN ADAMS, *Gen'l Supt.*

188

MR. JOHN ADAMS, *Gen'l Supt.*

Dear Sir:—In regard to the above, I have to say,

Yours truly,

For the Union Switch and Signal Company.

The returns from these blanks have not been posted in tabular form at the office, but Superintendent Adams kindly placed the blank returns from March 1 to August 1, 1884, in the hands of the writer, from which the following results were obtained :

Indicated Cause.	*Number of Indications.*
Train in section,	67
Switch open,	36
Work in section,	25
Unknown,	16
Broken track wire,	42
Decay of switch frame,	1
Rails driven together at end of section,	1
Dust on platinum points,	2
Broken spring in signal switch,	2
Bad zinc in battery,	9
Rails connected by crossing wire,	5
Derangement of signal apparatus,	9
Guard wire broken,	9
Bad insulation,	12
Lack of blue vitriol in battery,	4
Broken switch,	1
Battery wire broken,	3
Broken frog wire,	4
Loose-headed rivet,	3
Relay burned out by lightning,	3
Relay out of adjustment,	2
Signal slow in turning,	1
Signal weight ran down,	2

The failures recorded below the dividing line are to be charged to the system, and they may be taken as a fair indication of the character of the failures likely to occur. The number of failures however, varies greatly upon different roads. For example, the number of cases of broken track wire is here forty-two, while upon the Providence and Boston Road there was not a single case for three of the corresponding months. This disparity well illustrates the great improvements in construction, suggested by experience, since the first introduction of the signals. It is to be noted also that nearly all of these failures would be prevented by the exercise of greater care in the supervision of the signals. A new plant, of the latest form of construction, would probably reduce the number of failures by at least one-half. Even here the ratio of the number of failures to the number of operations is

$$117 : 144 \times 252 \times 27,$$
$$\text{or} \quad 1 : 8374.$$

The records of the service on this road do not show the number of cases in which a safety signal was shown when a danger signal should have been exhibited. According to the testimony of the officers of the road, only three such instances have occurred. It should be said that this is much less than the average number on other roads, where a strict record has been kept.

THE SIGNALS ON THE BOSTON AND PROVIDENCE RAILROAD.

The first five miles of this road out of Boston are equipped with sixteen signals. The number of regular trains daily is 106; the average number of irregular trains being about 25 daily. Engineers are furnished with blanks similar to those in use upon the Fitchburg Road, but no permanent record is kept, on account of the satisfactory operation of the signals. By the kindness of Superintendent Folsom, a copy of the failures for two months in 1884 was made, viz., from June 23d, the date of the introduction of the signals, to July 23d, and for October, 1884:

Indicated Cause.	*Number of Indications.*
Loose connecting screw,	1
Spring failed,	4
Relay out of order,	12
Switch-box out of order,	4
Battery out of order,	3
Signal apparatus out of order,	4
Water on the track,	3

It is the testimony of the officers of the road that a safety signal has never been shown when a danger signal should have been set.

EASTERN RAILROAD.

Record of the Union Switch and Signal Company signals from January 1, 1881, to December 1, 1884:

Trains in section,	352
Imperfect connections at draw-bridge,	13
Signal apparatus out of order,	4
Lightning burned out relay,	7
Broken battery,	9
Broken switch stand,	4
Broken rail at end of section,	12

Broken wires, ...	110
Loose pin in switch, ...	6
Trouble with magnet, ...	10
Trouble with switch instrument, ...	10
Signal weight run down, ...	6
Falling weight caught, ...	2
Banner caught, ...	1
Unknown, ...	6

Here, as on the Fitchburg Road, the greatest trouble appears to be with broken wires.

BOSTON AND ALBANY RAILROAD.

The records of the operation of the signals upon this road are kept with the greatest care, and in the most systematic manner, under the direction of Mr. Blodgett, the Electrician in Charge. The following very complete summary was kindly furnished in answer to an application to Mr. G. R. Hardy, the Engineer of the road:

BOSTON AND ALBANY RAILROAD COMPANY.

DIVISION I.

Union Electric Signals. October, 1883, to October, 1884.

Number of Blocks in Operation, 51 to 81.

			Ratio to Number of Operations.	
No. of operations,		1,083,291.		
Stops for trains in section,	1,648.		1/657	
Stops for switching,	31.		1/34945	
Stops for broken rail,		1,698.		1/863
Stops for repairing track,	18.		1/60183	
Stops for using single track,	1.		1/1083291	
Stops for neglect of trackmen,	238.		1/4552	
Stops for neglect of trainmen,	31.		1/34945	
Stops for neglect of towerman,	1.		1/1083291	
Stops for neglect of station agent,	83.		1/13052	
Stops for neglect of switchmen,	3.	696.	1/361097	1/1556
Stops for neglect of signalmen,	293.		1/3697	
Stops for neglect of carpenters,	4.		1/270893	
Stops for neglect of U. S. & S. Co.'s men,	42.		1/25793	
Stops for testing circuit,	1.		1/1083291	
Stops for signal failed to change, showing safety,	179.	502.	1/6052	1/2158
Stops for signal failed to change, showing danger,	323.		1/3354	
Stops for climatic conditions,	957.		1/1132	
Stops for unlighted signals,	199.	1,591.	1/5444	1/681
Stops for cause not known,	435.		1/2490	
Stops unnecessary,		2,789.		1/388
TOTAL,	4,487.		1/241	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

BOSTON AND ALBANY RAILROAD COMPANY.

DIVISION 2.

Union Electric Signals. October, 1883, to October, 1884.

Number of Blocks in Operation, 24.

			Ratio to Number of Operations.	
No. of operations,		251,976.		
Stops for trains in section,	4,290.		1/59	
Stops for switching,	9.	**4,340.**	1/27997	**1/58**
Stops for broken rail,	31.		1/8128	
Stops for repairing track,	10.		1/25198	
Stops for neglect of trackmen,	13.		1/19383	
Stops for neglect of trainmen,	1.	**60.**	1/251976	**1/4200**
Stops for neglect of station agent,	5.		1/50395	
Stops for neglect of signalmen,	41.		1/6146	
Stops for signal failed to change, showing safety,	46.	**204.**	1/5478	**1/1235**
Stops for signal failed to change, showing danger,	158.		1/1595	
Stops for climatic conditions,	213.		1/1183	
Stops for unlighted signals,	404.	**702.**	1/624	**1/359**
Stops for cause not known,	85.		1/2964	
Stops unnecessary,		**966.**		**1/261**
TOTAL,	5,306.		1/47	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

BOSTON AND ALBANY RAILROAD COMPANY.

DIVISION 3.

Union Electric Signals. January, 1884, to October, 1884.

Number of Blocks in Operation, 4 to 8.

			Ratio to Number of Operations.	
No. of operations,		114,693.		
Stops for trains in section,	6,249.	11,125.	1/18	1/10
Stops for switching,	4,856.		1/24	
Stops for broken rail,	4.		1/28673	
Stops for repairing track,	16.		1/7168	
Stops for neglect of trackmen,	25.	67.	1/4588	1/1712
Stops for neglect of trainmen,	1.		1/114693	
Stops for neglect of station agent,	3.		1/38231	
Stops for neglect of signalmen,	38.		1/3018	
Stops for signal failed to change, showing safety,	85.	336.	1/1349	1/341
Stops for signal failed to change, showing danger,	251.		1/457	
Stops for climatic conditions,	176.	425.	1/652	1/270
Stops for unlighted signals,	79.		1/1452	
Stops for cause not known,	170.		1/675	
Stops unnecessary,		828.		1/139
TOTAL,	11,953.		1/10	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

BOSTON AND ALBANY RAILROAD COMPANY

DIVISION 4.

Union Electric Signals. January, 1884, to October, 1884.

Number of Blocks in Operation, 6.

			Ratio to Number of Operations.	
No. of operations,		39,398.		
Stops for trains in section,	1,405.		1/28	
Stops for switching,	83.	1492.	1/475	1/26
Stops for broken rail,				
Stops for repairing track,	4.		1/9849	
Stops for neglect of trackmen,	9.		1/4378	
Stops for neglect of trainmen,		12.		1/3283
Stops for neglect of station agent,	1.		1/39398	
Stops for neglect of signalmen,	2.		1/19699	
Stops for signal failed to change, showing safety,	107.	201.	1/368	1/196
Stops for signal failed to change, showing danger,	94.		1/419	
Stops for climatic conditions,	60.		1/657	
Stops for unlighted signals,	136.	278.	1/290	1/142
Stops for cause not known,	82.		1/480	
Stops unnecessary,		491.		1/80
TOTAL,	1,983.		1/20	

(Signed) G. W. BLODGETT.

Approved, G. R. HARDY.

The signals upon this road were first used in April, 1882. The total number is about 100. The distance between the signal stations is about one-fourth of a mile as far as the Providence crossing, about one-half mile apart for two miles out, and for the remaining nine miles about one mile apart.

The numbers in the first column represent the useful work of the signals. The numbers in the second column represent the failures due to neglect on the part of employés in charge of the signals, and in the third section, the failures to be charged to the system itself. The figures in bold-face types represent the totals in each column.

It will be noticed that the number of failures due to climatic conditions is unexpectedly large. They are for the most part due to the completion of the circuit between the rails through water containing a large percentage of salt standing upon the track.

It will be seen also that the number of cases when a safety signal was shown when a danger signal should have been set, is apparently much larger than upon other roads. This is without doubt largely due to the strict accuracy with which the record has been kept. The number of broken wires is not shown separately in this report, but it is comparatively very small. The connections between the rails are now made with two wires instead of one, as formerly.

PROVIDENCE AND WORCESTER RAILROAD.

The study of the operation of the signals upon this road has been reduced to a science by the Superintendent, Mr. W. E. Chamberlain. His reports to the Railroad Commissioners of Rhode Island may be said to form the first complete demonstration from a discussion of the records kept of the feasibility of this system of signals in the ordinary operations of a road.

These signals were first put in operation in April, 1882. There are twenty eight on the first division, which extends from Providence to the Boston Switch at Central Falls. The signals upon the second division, which extends from Boston Switch to Worcester, thirty-nine miles, were introduced November, 1883. They number forty-eight. In the operation of these signals, engineers are governed by the following instructions:

(1.) When a signal shows danger you will come to a full stop before entering the block which said signal protects, or, if a special signal, you will come to a full stop before covering the switches it protects. You may then proceed carefully, but under full control, expecting to find the block obstructed, or a switch set wrong, or a rail broken. If no trouble is found and the next signal is at "safety," you may proceed at usual speed, but if at danger proceed as before from block to block until the obstruction is passed. Report all stops or detentions on blanks furnished for that purpose.

(2.) All signals now in use, and all rules in force governing the safety of trains, will continue to be used until further orders.

(3.) Study carefully the description of blocks and special signals.

Road masters and section foremen will thoroughly post themselves in regard to the working of the electric signals, and teach their men to keep the track wires and insulations in perfect order, bearing in mind that on you, in a measure, depends the proper working of the signals. No rail or frog must be changed (except in case of emergency), unless the foreman in charge of signals is on hand to make the proper connections.

At my request, Mr. Chamberlain has kindly made up a summary of the operation of the signals to October, 1884.

It is as follows:

ELECTRIC SIGNAL REPORT.

(FIRST DIVISION P. & W. R. R., DISTANCE 5 MILES.)

From October 1, 1883, to October 1, 1884.

The small figures in the spaces, indicate the number of failures; the large ones, the number of trains stopped.

Letters indicate switch signals only. Figures indicate track and switch signals.

A	B	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	C	20	F	X	H1	H	D1	D	TOTAL.			
		2	97	5	98	10	51	9	3	27		29	3	60	12	50	14	3	23	8	6				1		1	512	P. & W. trains stopped by B. & P. trains in section.		
																			1									1	B. & P. trains stopped by P. & W. trains in section.		
		1	55	1	80	10	39	3	4	21	20	13	7	14	10	8	12	3	5	3	3	1			1		1	315	P. & W. trains stopped by P. & W. trains in section.		
																1												1	Trains stopped by gateman at Pawtucket.		
			6	1	18		6	2	1	3	2	14	3	5	6	2	3	1	9		2							84	Trains stopped by unknown trains in section.		
							1		1				1															3	Trains stopped by hand cars in section.		
	3	2	12						1		1			1	2		3								6		6	37	Trains stopped by switch being open.		
		1	12																									13	Trains stopped by switching in Providence Yard.		
																			1									1	A freight car left on main track by train breaking apart.		
										1																		1	Trains stopped by switching at cattle track.		
												5			3													8	Trains stopped by switching at Sayle's Turn-out.		
												12	1	12	40	1	21	2	7	5								101	Trains stopped by switching at Pawtucket.		
																															TRAINS.
										$^{2}3$						$^{1}2$	$^{1}7$			$^{1}2$								5	Broken rails	stopped	14
								$^{1}1$		$^{1}1$					$^{1}1$													3	Switch boxes out of order	"	3
			$^{1}1$		$^{3}8$	$^{1}1$		$^{1}4$	$^{2}4$	$^{5}6$	$^{3}5$			$^{1}2$		$^{1}1$	$^{2}2$			$^{3}3$					$^{1}1$			24	Lights out	"	38
																													Failures on account of loose track wires	"	
				$^{1}2$	$^{3}7$	$^{2}3$	$^{1}3$			$^{4}9$	$^{6}9$	$^{1}1$	$^{5}16$	$^{1}1$		$^{2}2$	$^{1}1$		$^{2}7$									29	Failures on account of broken track wires	"	61
			$^{1}1$				$^{4}7$	$^{1}1$	$^{1}1$			$^{1}2$	$^{2}3$	$^{1}2$			$^{1}1$		$^{1}1$		$^{1}1$				$^{1}1$		$^{1}1$	16	Failures of machine	"	22
			$^{1}1$						$^{1}1$		$^{2}6$									$^{1}1$								5	Failures on account of weak current	"	9
	$^{1}1$											$^{1}1$	$^{1}1$			$^{2}2$		$^{1}1$	$^{3}3$		$^{2}3$							11*	Failures of battery	"	12
			$^{2}2$										$^{1}2$						$^{1}2$									4	Failures on account of track insulators giving out	"	6
									$^{1}1$																			1†	Failures on account of machines run down	"	1
			$^{3}4$	$^{1}1$			$^{1}1$	$^{2}3$		$^{2}2$				$^{1}2$	$^{1}1$		$^{2}2$			$^{1}1$					$^{1}1$			15	Failures on account of carelessness of employés,	"	18
		$^{2}5$			$^{1}1$	$^{2}2$	$^{1}2$		$^{1}1$		$^{2}7$			$^{1}2$		$^{1}1$			$^{1}1$						$^{1}1$			13	Failures on account of broken or crossed line or ground wires	"	23
									$^{1}1$		$^{1}4$								$^{1}1$									3	Failures for which no cause was found	"	6
			$^{1}1$																									1	Relay not adjusted high enough	"	1
																													79 Failures, not including lights out or carelessness, stopped 137 trains.		

* 6 of these account carelessness. † Carelessness.

GRAND TOTAL FOR BOTH DIVISIONS.

Total number of signals on First Divison, ...	28
Total number of signals on Second Division, . . .	48
	76 signals.
Total number of operations on First Division for the 30 months to October 1, 1884, ...	1,366,386
Total number of operations on Second Division for the 10½ months to October 1, 1884, ...	371,304
	1,737,690 operations.
Total number of failures on First Division for the 30 months to October 1, 1884, ...	341
Total number of failures on Second Division for the 10½ months to October 1, 1884, ...	99
	440 failures.

Percentage of failures to operations on both divisions, ... ·000253

565 trains stopped on First Division by failures of signals during 30 months.

Total number of trains run on First Division during 30 months, . . 97,600

Percentage of trains stopped by failures, ... ·005789

165 trains stopped on Second Division by failures of signals during 10½ months.

Total number of trains run on Second Division during 10½ months, ... 15,471

Percentage of trains stopped by failures on Second Division, . . ·010665

Total percentage of trains stopped by failures on both divisions since signals have been in operation, ... ·006456

The writer has not had an opportunity of inspecting the operation of the pneumatic signals of the Union Switch and Signal Company. They have not been in operation for a sufficient length of time for the accumulation of the data necessary to a complete discussion of their performance. In the absence of a continuous record, the following interesting communication from Mr. Childs, General Superintendent of the Walkill Valley Railroad Company is given, as indicating the general performance of the signals.

NEW YORK, ONTARIO AND WESTERN RAILWAY COMPANY.

[redacted]

(Report of Examiners, Section XXII.)

rains stopped

Total	
4	Train or car on side track too near main
473	P. & W. trains stopped by P. & W. trains in section.
16	Trains stopped by unknown trains in section.
6	Trains stopped by hand cars in section.
19	Trains stopped by switch open in section.
	Trains stopped by switching at Valley Falls,
	Trains stopped by switching at Lonsdale.
33	Trains stopped by switching at Woonsocket.
42	Trains stopped by switching at Waterford.
1	Trains stopped by switching at Quinsigamond.
5	Trains stopped by switching at South Worcester Yard.

			Trains.
5	Broken rails	stopped	12
7	Switch boxes out of order	"	10
58	Lights out	"	76
	Failures on account of loose track wires	"	
4	Failures on account of broken track wires	"	4
46	Failures of machine	"	87
	Failures on account of weak current	"	
3	Failures of battery	"	7
6	Failures on account of track insulators giving out	"	9
19	Failures on account of machines run down . . .	"	37
21	Failures on account of carelessness of employés	"	31
10	Failures on account of broken or crossed line or ground wires	"	19
3	Failures for which no cause was found	"	3
3	Brass springs rusting	"	5
1	Water in post, chain frozen, ...	"	1
1	Door loose, ice on chain, ...	"	2
12	Relay damaged by lightning	"	13
1	Repairing track	"	2
1	Switch frame worked away from plunger of switch box	"	2
1	Run down by hand car	"	1

99 failures, not including lights out or carelessness, stopped 165 trains.

intervals of three-fourths of a mile we have established se
signals for each track. These signals are located at point

GRAND TOTAL FOR BOTH DIVISIONS.

Total number of signals on First Divison 28

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Valley Railroad Company is given, as indicating
rmance of the signals.

NEW YORK, ONTARIO AND WESTERN RAILWAY COMPANY.

Walkill Valley Railroad Company.

General Superintendent's Office, No. 24 State Street.

J. E. CHILDS, *General Superintendent.*

NEW YORK, November 13, 1884.

THOMAS W. SPENCER, C. E., *Inspector for Board of Railroad Commissioners, of the State of New York, Utica, N. Y.*

Dear Sir:—I am in receipt of your favor of November 11th, and take pleasure in giving you information in relation to the electric and pneumatic signals.

These signals, as you are aware, are located upon thirteen miles of the West Shore Road, immediately south of Cornwall, which is operated by this company under a long lease.

This portion of the track used by the West Shore and Ontario and Western Companies, lies along the foot of Dunderberg, Storm King, Cro' Nest, and other mountainous regions of the highlands of the Hudson, where the rocky cliffs on the one side and the very deep water on the other necessitates many sharp curves. In some cases the water in the river was ninety feet deep, only twenty feet from the shore with bottom of shelving rock, where we were unable, to make an embankment, and were obliged in several instances to put in long spans of iron bridges. We also have on this thirteen miles two jack-knife draw-bridges, one Cantilever bridge, one tunnel, and the sharpest curves upon the road.

It was considered advisable on account of these objectionable features of this portion of the line, to place upon it the best system of automatic signals that could be found. Mr. George Westinghouse, of Pittsburg, having just procured letters-patent, upon his automatic, electric and pneumatic block signals, we arranged with him to equip this thirteen miles of the line.

The power used for compressing the air is furnished by two ten horse-power engines located near either extremity of that portion of the line which is covered with the block signals.

The air, after being compressed, is passed through coils of pipe and two cylinders where it is cooled, after which it is sent through a pipe one inch in diameter which is laid between the tracks. At intervals of three-fourths of a mile we have established semaphore signals for each track. These signals are located at points, where

they can be seen for the greatest distance, and are connected by a pipe with the main air pipe lying between the tracks. The signals are operated by compressed air cylinders, the valves of which are controlled by electric currents, one of which passes over the line on telegraph poles and the other through the rails. The signals are controlled by short circuiting electric current in the rails when a train or engine passes over the track, the current passing through the wheels and axles from rail to rail. Opposite each semaphore signal is a battery well built of brick below the surface of the ground, and contains for each semaphore signal a seven jar battery.

When a train passes into the block, the signal immediately behind the train shows both arms at a horizontal position by day, and two red lights by night; this is called an absolute danger signal; or the second "danger" position. The second signal from the rear of the train shows the upper arm in an inclined and the lower arm in a horizontal position by day, and a red and white light by night; this is called the first danger position.

You will see by this system that when one train follows within one mile and a-half of another, they are warned that a train is preceding them and the first appearance of the signal not only indicates danger, but absolutely locates it; for instance, if the engineer sees a signal with the upper arm inclined and the lower arm horizontal, or showing a red and white light, he knows that a train is ahead of him, but that the block immediately ahead of this signal is clear and that the train or obstruction is upon the second block. If he sees a signal with both arms projecting in a horizontal position, or showing two red lights, he knows that the danger is imminent and that the train or obstruction of some nature is upon the block ahead of this signal.

I enclose a book of instructions to employés, which, without describing the details of the signals at all, gives them all the information which they require and shows the simplicity of the system.

In addition to this, we have every switch upon this portion of the line interlocked with the circuit in the track in such a manner that whenever the switch is opened two danger signals are shown upon the main track from which the switch is turned. The electric current also passes into the rails of the side tracks out to the clearance distance, so that should a car, standing on the side track, be moved by malicious persons, or should it be blown by the wind to a point

where it might interfere with the traffic, two danger signals are immediately placed automatically on the track in the direction from which trains approach.

We also have two draw-bridges which are connected with this system in the following manner: The two jack-knife bridges on this portion of the line are connected with this system without changing the form of the automatic signals, two of them being made to act as distance and home signals for the draw-bridge. When a train approaches within 8,000 feet of the bridge, an electric bell is sounded continuously directly over the head of the watchman who attends to the draw-bridge, warning him that the train is approaching and that he must not open the draw. This bell rings from the time the train passes over a point 8,000 feet until it passes a point 7,000 feet from the draw-bridge when the gong ceases to sound. If, during the time the train is running from the 8,000 feet to the 7,000 feet point, the watchman should, contrary to instructions, undertake to open the draw-bridge, he cannot do so without first setting two danger signals in the face of the train while the train is still one and one-half miles distant from the bridge. After the train has passed over the point 7,000 feet from the draw-bridge, the draw-bridge is locked by electricity and cannot be opened. As these draw-bridges are on double track the signals operate in the same manner for both directions.

This I consider a very perfect system for the protection of a draw-bridge, and I could only suggest one improvement, which we are now considering; that is, to have a switch near the draw-bridge which shall throw the train off the track rather than let it into the draw in case the engineer disregards the signals.

We also have some crossings protected by electric bells, which ring at the crossing when a train approaches from either direction within one mile, and the bell continues to ring until the train has passed the crossing.

We also have, aside from the block system, an electric tunnel block signal, protecting trains while passing through Haverstraw Tunnel, which works automatically. When a train reaches a point within 2,000 feet of the tunnel, by short circuiting an electric current in the track, a danger signal is set in the rear of the train, which remains at "danger" and prohibits other trains from entering the tunnel until this train has passed entirely through, and 2,000

feet beyond the tunnel, when the signal goes to "safety," and the track is clear for following trains.

I have kept an accurate account of all failures which have occurred upon the line, and have sent copies of monthly report to the General Manager of the Union Switch and Signal Company, of Pittsburg, and am assured by him that the percentage of failures is much less than upon any other systems of signals that has ever been invented.

Enclosed I send you a copy of report of failures of the signals for the month of October. During this period 1,065 trains passed over this portion of the line. There are in all forty-five signals, including the home and distance signals for the draw-bridges, making 47,925 signal movements during the month. From the attached report, you will see that the total number of failures during this period were, including October 28th, when a break occurred in the main pipe at Fort Montgomery, which set all signals at danger, was sixty-eight failures, or about one-seventh of one per cent.

Report of Failure of Automatic Semaphore Signals on New York, Ontario and Western Railway Company, Hudson River Division, October, 1884.

Date.	*Number of Semaphore.*	*Nature and Cause of Fault.*	*Position of Blade.*
1	37 and 39	Broken battery jar.	Danger.
2	36	Weak battery.	Danger.
10	1, 9, 15, 17	Broken battery jar.	Danger.
14	19	Weak battery.	Danger.
17	7 and 9	Broken guard rail	Danger.
17	18 and 20	Track wires out of rail, on Iona Island trestle.	Danger.
18	23	Broken jar.	Danger.
20	25 and 27	Broken jar, leak in main pipe caused by slack union.	Danger.
24	36	Broken jar.	Danger.
26	9, 9 and 11	Weak battery.	Danger.
26	27	Spike between cross-over rails at West Point.	Danger.
27	9	Signal would not go to danger; armature screwed down, could not open.	Safety.
28	all	Break in main pipe at Fort. Montgomery.	Danger.
31	12 and 14	Weak battery.	Danger.

(Signed) G. W. BRADLEY, *Supt. Hudson River Div.*

To J. E. CHILDS, *General Superintendent.*

You will observe that, with only one exception, the signals went to danger, and consequently caused no harm, other than a slight delay to traffic.

These signals have been in operation since April 1, 1884, and in that time but two failures of the signals where they were at safety, and should have indicated danger, have been reported.

You will also observe that a number of failures occurred through broken battery jars. We find these jars were too light, and are now substituting heavier ones.

You have no doubt seen reported in the papers that an engine ran into Popolopen (? Ed. Com.) draw-bridge, in the month of October. This was not through any failure of the signals, as the engineer admitted having passed the distance signal 7,000 feet, and a home signal 650 feet from the draw, both set at danger.

From experiments recently made, I believe that this thirteen miles of automatic block signals can be operated with one engine if located at a point about the centre of the system, and I shall make the change in a few weeks, which will reduce the cost of operating the signals.

I shall be glad to furnish you any other information on the subject at any time.

Yours truly,

(Signed) J. E. Childs, *General Supt.*

The HALL SYSTEM.

The only road completely equipped with this system is the New York and New Haven Railroad. In view of the fact that the order of the superintendent of this road, that no engineers shall in any case enter a section until a safety signal is shown, is an iron-clad rule, whose violation is immediately followed by removal, the inference may be fairly drawn that the mechanism of this system is very perfect and very certain in its action. Inasmuch as an official statement of the observance of this rule would add greatly to public confidence in the value of the system, a letter of inquiry was addressed to Hon. Geo. H. Watrous, President of the road. In reply, the following communication was received:

OFFICE OF NEW YORK, NEW HAVEN & HARTFORD RAILROAD COMPANY.

NEW YORK, February 7, 1885.

HON. GEORGE H. WATROUS, *President, etc., New York.*

Dear Sir:—In reply to yours, asking for report of the performances of the Hall's Signals, now in service on New York Division, I would say: They have never failed to perform their service; that is, they never have failed to show danger when they should.

The principle in their construction is such that, if the battery is not kept up, or if the wire breaks, or any of the mechanical parts give out, the signal will immediately go to "danger," and will remain so until it is attended to; the normal condition of the signal being danger.

It is the electric current that holds the signal up clear.

Since the signals have been in operation on the New York Division, we have had trains stopped on account of signal showing danger (when there was no train in the section ahead) from the following causes:

Weak battery, 18 times;	Stuck spindle, 5 times;
Broken wire, 3 times;	Loose connection, once;
Broken levers, 3 times;	Wires crossed, 4 times;
Weak spring, 3 times;	No cause given, 3 times.

Below please find answers to the questions which Mr. Rogers asks in his letter to you, and which you desire me to answer.

Question First: "Do the signals ever indicate 'safety' when they should indicate 'danger,' and under what circumstances or conditions?"

Answer: No; the signals *cannot* show "safety" when they should indicate "danger." When a train has set the signal, it cannot be cleared until that train has passed out of the section, running over the release, or cleared by the agent at the station.

In explanation, I would say, that there is a key in the ticket office, at the station where the signals are located, which allows the agent to clear the

signal, after it has been set by a train passing over it, and that train (instead of going beyond the station and running over the release) stops and goes in on a turn-out at the station. When the train is in on a turn-out all clear, the conductor reports to the agent, and he can then clear the signal to let another train come along.

Question Second: "As a matter of railroad economy, is the operation of the signals so nearly perfect, that you can afford to enforce the iron-clad rule of absolutely forbidding the entrance into a section until the signal passes from 'danger' to 'safety'?"

Answer: Yes, that is just what we are doing. No train is allowed to pass a signal when it shows red, without orders to do so.

In explanation of this I would say, if a train reaches a signal and it shows red, the train stops.

After the train has remained there ten minutes and the signal does not clear, it indicates either that the signal does not work, or else something has happened to the train that is ahead in the section.

Under these circumstances, when the train that is stopped by the red signal, has remained there ten minutes, it is then (as required by our rules) ten minutes behind the preceding train.

The conductor then has orders to send his brakeman ahead with a red flag, and after he has been gone five minutes, he can allow his train to follow, running very slowly (not over five miles per hour), until the next station is reached. There the train stops, and the conductor goes to the station telegraph office and reports to the Superintendent.

If there is no train ahead of him in the section, it shows that the signal is not working. He then receives orders from the Superintendent to proceed, and the station agent receives orders to put a green disc in that signal case, which indicates that the signal is out of order and trains can proceed through that section very cautiously.

In conclusion, I would say that, since the signals have been placed upon the road, I have watched them closely. There has never been any failure, so far as I know, in their working. As I said before, if anything happens to the wire, or the current is destroyed, or the mechanical parts need renewing, the signal immediately goes to "danger" as it should; *but the signal cannot show "clear" when it should show "danger,"* and I would feel perfectly safe with the Hall Signal, knowing that if they were used over the entire length of our road as a block system, one train could not possibly be in the section with another train, at the same time, if the signal was obeyed.

Respectfully yours,

WILLIAM H. STEVENSON,
Superintendent.

This positive testimony in favor of the Hall system would seem to indicate that it is well adapted to meet the complicated requirements of a great railroad. The improvement over the old Hall, or open circuit system, is very marked. It should be said,

however, that the old Hall system is still in successful operation on the Worcester Division of the Boston and Albany Railroad. Daily and monthly reports of the operation of these signals are made up in the office of the engineer of the road, showing results, which though not equal to those obtained under the Union Switch and Signal Co.'s system at the Boston end of the road, are however, quite satisfactory. In illustration of the great improvement which has been made since the introduction of electric signals, the following reports are extracted from the Report of the the Board of Railroad Commissioners of Massachusetts for 1880, pp. 210, 211.

REPORTS ON THE OPERATIONS OF ELECTRIC SIGNALS.

BOSTON & ALBANY RAILROAD COMPANY,
BOSTON, December 13, 1879.

Dear Sir:—In reply to your questions concerning the Hall Signals, I send you a comparative statement for the years ending November 30, 1878 and 1879. The whole number of stops made by trains in 1879, caused by other trains in the section, was 1,689. Stops made for cause unknown, 1,573. So far as we can tell, these stops were unnecessary. The number of signals not working is 4,344. In these cases caution would be indicated, and the danger signal would not be shown to a following train, during the time the preceding train was in that section. We continue our rules for guarding the rear of trains, and do not rely upon the signals at any time. Connected with switches and bells at highway crossings, the system works very very well. There are 39 signals east of South Framingham which are operated 2,748 times daily (Sundays excepted), and 350 times on Sunday.*

Yours respectfully,
W. H. BARNES.

D. W. LINCOLN, Esq., *President Boston and Albany Railroad.*

Comparative Statement of the Working of Hall's Signals for the Year Ending November 30, 1878 and 1879.

	1878.	1879.
Trains stopped by another train in section, .	1,612	1,689
Trains stopped, cause unknown, ...	624	1,573
Failed to work, ...	2,800	4,344

* The product of the number of signals, multiplied by the number of trains passing and acting on them during the year, is 878,324, and is the number of times requiring the movement of a signal; so that the number of reported failures to act—4,341—is one in 202 times.—*Commissioners.*

EASTERN RAILROAD COMPANY,
BOSTON, December 22, 1879.

W. A. CRAFTS, Esq., *Clerk Board Railroad Commissioners.*

Dear Sir:—In reply to your inquiry for information in regard to the working of our automatic signals during the past year, I will give the following information:

As you will recollect, I made a report on 12th of August, in which was briefly described the working of our modified Hall system, with a list of its failures during a period of some months.

Since that date the operation has been still more satisfactory; as, for instance, in November, when, from approach of winter, an increased number of failures might naturally be expected. The following are the facts:

Whole number of stops during month, 27.

CAUSES.

Spindles stuck,	8
Wires crossed,	3
Section men moving material,	1
Trains in section,	15
	27

On the whole, while the system is not perfect, it has given very fair satisfaction, and is a great help to the safe and economical working of the road.

Up to the present time know of nothing better.

Yours truly,
E. B. PHILLIPS,
President.

FITCHBURG RAILROAD,
BOSTON, MASS., Dec. 12, 1879.

Hon. THOMAS RUSSELL, *R. R. Commissioner, No. 7 Pemberton Square, Boston.*

Dear Sir:—Your favor of the 8th inst., addressed to the President, in relation to the Union Electric Signal Company's signals in use on this road, has been referred to me.

Please find enclosed herewith a tabulated statement, which I have had prepared for you from the reports rendered by the enginemen, showing the number of times the signals have been found at danger, and the causes, from May 1 to November 15, 1879, inclusive.

The total number of regular week-day trains, which have passed over the larger portion of the signals, during the period covered by this statement, is 12,312; and the number of extra trains, shifting engines, etc., is undoubtedly half as many more, making the total number of week-day trains 18,468, which is an average of 108 trains per week-day.

We think they are a success, and that they add materially to the safety of the trains. An important feature in this system is, that, if it fails to operate, it cannot endanger the trains.

For further information in regard to them, I would refer you to my communication of August 15th last, addressed to your Board in response to inquiries upon the subject, as the facts remain substantially unchanged.*

Respectfully, JOHN ADAMS,
General Superintendent.

Tabulated Statement of Reports in regard to Electric Signals found at Danger on the Fitchburg Railroad, from May 1 to November 15, 1879, inclusive.

MONTHS.	Train in Section.	Broken Rail.	Hand-car in Section.	Misplaced Switch.	Trackmen Working in Section.	Cause not known.	Signal Wires, etc., being out of Order.	Interruptions caused otherwise than by Trackmen.
1879.								
May,	24	. .	1	1	1	1	7	. .
June,	19	. .	1	3	. .	2	16	. .
July,	12	. .	1	2	9	11	27	. .
August,	1	. .	. .	. .	. .	6	26	1
September,	7	. .	6	1	1	5	35	. .
October,	2	. .	. .	1	1	4	26	2
November to the 15th inst.,	. .	. .	. .	. .	2	. .	14	. .
	65	. .	9	8	14	29	151	3

* The number of signals is thirteen.

The RAILWAY CAB ELECTRIC SIGNAL COMPANY.

This system is in use in this country only upon the Staten Island Railroad. At the time of the inspection already referred to, it had been in operation about four weeks. According to the report of the engineer of the train, there had at that time been no failure.

The system was first tested in Austria. The company offers the following testimony of its successful operation there:

[*Translated Copy.*]

IMPERIAL ROYAL DIRECTION OF THE STATE RAILROADS OF AUSTRIA IN VIENNA.

No. $\frac{66}{11}$. VIENNA, February 24, 1884.

The Honorable, Sir Thomas C. Miles, Colonel and Adjutant:

In reference to your honored favor of January 19th, I honor myself to communicate to you the following: The experimental section is situated beyond Purkersdorf, where the Putnam signal system is being tested; to prove, first, the insulation of the rails, and, second, the sure and continued sounding of the whistle signal on moving trains, which has been operated since October 14, 1883. From this date, October 14th, to the end of December, 1883, the locomotive provided with the signal machinery ran sixty-three times. In two cases the function failed, namely, on November 10th and December 24th, in consequence of disturbances in the dynamo machine; while in sixty-one cases the apparatus acted normally. The tests will be continued and further results communicated to the Honorable Sir.

The First President,

(Signed) CZEDIK.

[*Translated Copy.*]

IMPERIAL ROYAL DIRECTION OF THE STATE RAILROADS OF AUSTRIA IN VIENNA.

No. $\frac{66}{11}$. VIENNA, May 8, 1884.

The Honorable, Sir Thomas C. Miles, Colonel and General Manager:

In answer to your favor of March 23d, I honor myself by communicating to you that the failures in the operation of the Putnam signal alarm apparatus in the section of experiment near Kellerwiese, which took place November 10th and December 24th, of last year, and mentioned in the letters $\frac{66}{11}$, according to the investigation made on this subject, were called forth by defects in the mechanism on the locomotive, and not by the constructive principle of the Putnam system.

For the Imperial Royal Director,

(Signed) SIEGEL.

[*Translated Copy.*]

IMPERIAL ROYAL DIRECTION OF THE STATE RAILROADS OF AUSTRIA IN VIENNA.

No. $\frac{3081}{11}$. VIENNA, July 1, 1884.

The Honorable, Sir Thomas C. Miles, Colonel and Adjutant:

In answer to your esteemed letter of June 18th, I honor myself by communicating to you in reference to my letter, No. $\frac{66}{11}$, dated February 24, 1884, that the locomotive equipped with the Putnam signal system machinery, has run on the section near to the station Kellerwiese, 244 times, from the first of January to the last day of May, and the alarm apparatus has operated normally, with the exception of two cases. These two cases occurred on the 31st of January and 10th of April, and the cause of the first case was the tearing of the wire of connection between the locomotive and the tender; in the second case, by the magnet becoming loosened.

The First President,

(Signed) CZEDIK.

Extracts from a voluminous report of the Imperial Royal Austrian State Railways, made at Vienna, December 5, 1884:

This engine has passed over the insulated points near Kellerwiese from October 15, 1883, to August 21, 1884—350 times, and in these 350 trips the apparatus has failed to operate, that is, the steam whistle has not blown, five times. These five failures occurred on the following dates—November 10, December 24, 1883, and January 31, April 10, and July 6, 1884. The first failure was owing to the fact that the armature did not fall on account of a bent screw, the second was due to the failure of the steam valve; the three other failures were caused by the breaking of the wire between engine and tender. As far as the introduction of an automatic system of railroad signals may be considered desirable, it must be admitted that the Putnam system is far ahead of any other.

In conclusion, the following report of Mr. Kintner is added as an independent estimate of the three systems of signals offered for examination. The objections noted in my examination are nearly identical with those enumerated by Mr. Kintner. It will be sufficient, therefore, to refer to his report:

NOTES OF C. J. KINTNER UPON EXHIBITS OF RAILWAY SIGNALS.

OCTOBER 3, 1884.

PROFESSOR W. B. ROGERS.

Dear Sir:—In conformity to your verbal request of the 2d inst. to the effect that the Sub-Committee on Railroad Signals, of which you are Chairman, should offer individual suggestions upon which to base your report, I beg to offer the following:

The exhibits are:

(1.) The Putnam Cab Company.

(2.) The Hall Signal Company.

(3.) The Union Switch and Signal Company.

Taking them in the order named, I will pass upon them as follows:

The Cab signal embraces:

(1.) A block signal system.

(2.) A road crossing signal system and gate.

(3.) A misplaced switch and bridge.

The desirable features, which make it particularly valuable, are:

(*1.*) Audible signals are given of the condition of the track crossings, etc., on board the locomotive by a trembler bell, which warns the engineer by ringing that danger is imminent. This feature is valuable in itself, in view of the many accidents which occur through color blindness, and where night signals are set. It is sure of action (provided the electrical circuits are carefully secured) in all kinds of weather, foggy, rainy or during blinding snow. These features commend the system. The block arrangement appears to be effectual, and so far as I can ascertain, very certain in its action. I think with properly insulated circuits, there can be no question as to the efficiency of this system. The drop gates also deserve commendable mention for the simplicity and ease of action, thus rendering road crossings more secure against a dangerous class of accident. I think this feature deserves especial notice in behalf of the public welfare.

The operation of the signaling electro-magnetic apparatus by a dynamo, driven by an engine on the locomotive, is also a very desirable feature, rendering the signals independent of batteries, which are uncertain in their action and troublesome to keep in working order. As to the advisability of independent conductors apart from the rail, as before indicated, perfect insulation and secure fastenings for the wires should be used to render them free from mishaps due to weather and track walkers.

This system is based solely on Putnam's patents.

It is to be noted further that there are no mechanical signal arms, operated by mechanism, liable to get out of order, a very essential element, I take it, in any such apparatus. With this mechanism, as in all devices where positive action is demanded, unvarying in its actions from time to time, this is a very desirable feature.

As to demerits, there is, in my opinion, one essential element lacking, viz.: a means of showing the condition of the track on intervening portions of the sections, such as broken rails, a car blown or run by accident from a siding on to the main track. These features must enter into the discussion, and are, in my opinion, all-important in a system upon the accuracy of whose action lives and property depend. Nor does this system adapt itself for railroad crossings in the nature of blocking the egress and ingress of trains within limits of the crossings.

(*2.*) *The Hall Signal Company.*

This system embraces:

(1.) Block signals.
(2.) Switch signals.
(3.) Railroad crossings.

Aërial or insulated conductors are used independent of the rails. The road divided into sections has three signals dependent upon each other, so that an incoming train sets the signal near at hand at "danger," releases the rear signal at the rear end of the section from which it is passing, and sets it to "safety;" sets the distant advance signal to danger, and all are connected by interlocking mechanism, such that only a proper progress of the train actuates the signals in their order. The system is undoubtedly a good one, very positive in its action, works well, and has been in action, I am advised, on several railroads, where it gives satisfaction.

I doubt whether the vertically-swinging signal is a good one in any system, inasmuch as there is too much strain upon the parts where levers have to be used to raise an arm from vertical to horizontal, and mechanism acting in such a manner is liable to get out of repair. There is the further objection to such systems, that there must be absolute attention given to winding up the signaling actuating mechanism, to repairing the parts, and oiling the bearings, restoring the batteries, etc., etc. I point out these features to show wherein the audible signal excels the visual, inasmuch as the mechanism is much simpler. These suggestions have their bearing on the question of general efficiency.

As to the railroad crossing signal in Hall's system, I can say its action is all that could be desired, and the interlocking of the signals, so that trains cannot approach a crossing, without violating orders, until a safety signal is given, deserves mention.

Hall also shows a very desirable, slow-moving circuit closer, for action when the train is under full speed, which is accurate in its action and deserves mention. I refer to the rubber-cushioned lever, with piston attachment. It will not easily get out of repair.

The apparatus for moving a misplaced switch is quite positive in its action, and appears to be an effectual apparatus.

My objections to the system are:

(1.) Uncertainty of contact by mechanical circuit closer may occasionally render the signals inoperative.

(2.) Mechanism for raising and lowering signals requires more than a minimum attention.

(3.) Batteries require attention and are uncertain.

Advantages are in the security offered by causing each signal to control both the advance and rear signals automatically and keep them displayed until the next succeeding section is reached. This company work under Hall's patent exclusively.

(*3.*) *The Union Switch and Signal Company.*

This company work under the patents of Pope, Gassett, Robinson, Fisher, Westinghouse and others, and their system embraces an aggregation of the several features disclosed in these patents.

The main features embraced in their system are as follows:

(1.) Block system.

(2.) Railroad crossing block.

(3.) Misplaced switch.

(4.) Controlling switches from signal-man house pneumatically.

(5.) Audible signal at road crossing during the short period prior to and after passing said road.

(6.) Derailment of train at a railroad crossing, if the engineer fails to stop in time after a danger signal is displayed.

(7.) Broken rail indicated on entering the section.

(8.) Pneumatic controlling apparatus for actuating the switch and signals.

The system, as a whole, is quite complex; but the mechanism appears to be of substantial nature and quite positive in its action.

The advantages appear to be:

(1.) That in the use of the rails for conveying the electricity, a positive index is placed upon the rails themselves for indicating a break or rupture at any point within each section, and for indicating if a car has been blown from a siding upon the main track.

(2.) A misplaced switch is for a like reason indicated.

(3.) The blocking is made doubly secure by being so simple in the action that by a train backing off a section, the signals are all set at "danger," both in the rear and in advance.

(4.) The constantly ringing safety bell before and after passing a road crossing are decidedly desirable attachments.

(5.) The pneumatic apparatus is simple and decidedly positive in its action. As to liability to get out of repair by wear of packing, leakage, etc., I should think there might be such a liability.

(6.) The derailment of a train at a crossing I can hardly commend, it being questionable whether it is better to endanger the lives of passengers by a certain accident in view of a probable accident.

(7.) The horizontal swinging signals known as the Gassett and Fisher signal used by this company are much simpler, and mechanically much easier to actuate than the vertical or arm signal, and by their swinging vanes attract attention. Respectfully submitted.

C. J. KINTNER,
Sub. Com. on R. R. Signals.

ELECTRIC TIME SIGNALIZER.

This apparatus is intended for purposes where time signals are required; automatically securing precision of time in the moving of visual signals, sounding of bells, or production of the various mechanical movements desired in the warning and departure of railway trains, street cars, ferry boats, or where schedule time is required.

To effect this object, a mechanism is employed, which consists of a clock having a dial of an insulating substance, divided into twenty-four divisions, representing two series of twelve hours each. denoting the divisions of the day, and subdivided into minutes, and a hand or pointer carrying mechanism for changes of schedule.

There are also placed concentrically on the dial, metal rings denoting the divisions of time, with slots and contact points. The body of the pointer has within it a rotating shaft, making one revolution in seven days, which has on it a calendar cylinder denoting the days of the week, and discs containing contact pins, which are placed over their respective rings and contact points, which, at designated times, make an electric contact, closing the circuit, within which circuit are signaling bells, gongs, semaphores or other calling, warning or mechanical device.

Any number of electric circuits with any number of rings can be opened and closed by the pointer and its attachments.

On Saturday, at midnight, it automatically changes for the Sunday schedule, and resumes week-day work at midnight of Sunday.

A swift moving minute hand can be employed, to show minutes and seconds, if desired.

Changes from summer to winter schedule can be made in a few minutes.

The signals can be made on a bell or bells of any size, at any distance from apparatus. The apparatus can be used in any large school, where a number of class-rooms exist, and if required, different calls may be made for each day of the week.

A small apparatus with a single or double belt, would answer for all ordinary work.

In case the time-table cannot be carried out, owing to obstructions or other causes, a convenient switch cuts out the particular belt or belts, and a hand push-button would then be used, until the time-table can be restored, when the apparatus will take charge. The buttons can also be used for extras or specials.

REPORT OF SUB-COMMITTEE ON METEOROLOGICAL AND OTHER REGISTERS.

PROFESSOR M. N. HARRINGTON, *Chairman*.

CUSHING'S VELOCIMETER.

This is an adaptation of Morse's printing machine to the purpose of measuring high velocities. On a ribbon of chemical paper, press three electric pens, which leave a trace on the paper when the current passes through them, and none when the current is broken. The paper is unrolled by a hand crank, and kept properly taut by suitable appliances. Of the three circuits, one passes through a vibrating piece of metal in such a way that the circuit is made and broken at each vibration. The time of vibration being ascertained, this serves as a convenient and sufficiently accurate time measurer, each beat leaving its mark on the prepared paper. Of the other two circuits, one is broken at the beginning of the record, the other at the end.

The special excellencies of the velocimeter, claimed by the inventor, are:

(1.) Its extreme simplicity. It can be handled by a non-expert after a few minutes' instruction; there is no mechanism to get out of order, and no part of the instrument that, in case of breakage, cannot be repaired at small cost.

(2.) Its absolute accuracy and precision. The instrument exhibited will measure the $\frac{1}{1000}$th part of a second, but a reed could be used that would give a measurement as small as the $\frac{1}{5000}$th part of a second.

(3.) Its portability. There are only two small instruments in the system, and they can be packed in a box fifteen inches cube, and easily transported.

(4.) It makes a record of all observations, that may be filed away for future reference, a feature, I think, possessed by no other velocity measuring device.

This principle of recording small periods of time can be adapted to timing horse races, measuring the speed of ships at sea, measuring the velocity of sound, etc.

The apparatus was tried in measuring the speed of a rifle ball, and its working was entirely satisfactory. The instrument is undoubtedly accurate, simple, and very portable, and we can commend it highly.

ELECTRO-PNEUMATIC VALVE.

The Milwaukee Electric Manufacturing Company, of Milwaukee, Wis., manufacturers of electrical specialties, exhibited the Johnson electro-pneumatic valve, in its applications for controlling steam and air passages, of which the following is their description:

The novelty of this invention broadly consists in the application of a fluid under pressure as a motive force for operating valves or passages for fluids, the fluid under pressure being electrically controlled, *i. e.*, an expansible chamber is mechanically attached to a main valve; the fluid under pressure is admitted and

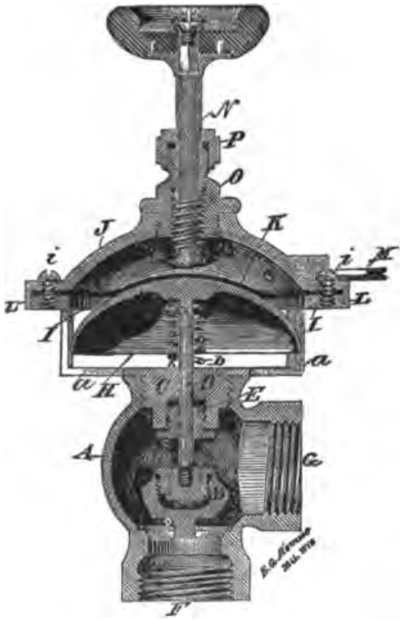


FIG. 23.

released from the expansible chamber, thereby actuating the main valve, the admission to and release of the fluid from the expansible chamber being electrically controlled. In order to make the actual construction of the apparatus more clearly understood, reference is made to the accompanying sectional view of an angle valve as actually constructed. (*See Fig. 23.*)

A is the chamber of the main valve, *F* being the inlet and *G* the outlet orifice. *B* is the valve disc, which closes downward upon its seat, thereby closing the passage. The stem *D* of the

disc is furnished at its opposite and external extremity with an inverted saucer *H*. The valve is held normally open by the steel spring *b*, placed between the saucer *H* and the plug *C*. External leakage is prevented by the stuffing box *E*, through which the stem *D* plays vertically.

Supported by the standards *a a* is the concave metallic cap *J*. Stretched across the under side of this cap, from *L* to *L*, is the flexible *K*. By means of a number of screws, as *i i*, the periphery of the diaphragm *K* is held tightly against the cap *J*, thus making an air-tight chamber between *K* and *J*. It is evident that if a fluid under pressure is admitted into this chamber through the tube *M*, that the valve *B* will be pushed downwards to its seat.

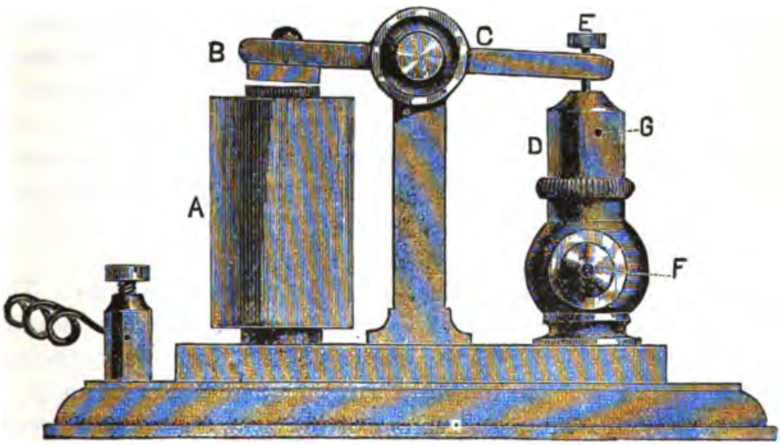


FIG. 24.

The force with which the valve *B* is seated will, of course, be proportioned to the area of the diaphragm *K*, pressure to unit of area remaining constant, the total force exerted at any time being the product of pressure per unit of area into the total area. In the valves shown, the proportional area of the diaphragm *K* to the area of the valve *B* is as 13 to 1, so that a fluid of less than ten pounds pressure admitted to the expansible chamber will properly actuate a main valve driving against 100 pounds pressure per unit of area.

The electrical mechanism used to admit and release the fluid from the expansible chamber is shown in the above cut, which represents a side elevation.

A is an electro-magnet; *B* its armature; *C* a lever adapted to raise the rod *E*, when the circuit is closed through *A*. Within *D* is the mechanism for the admission and release of the fluid under pressure from the expansible chamber, shown in *Fig. 24*. This mechanism may be termed a frictionless three-way cock. When the circuit is completed, the fluid is admitted to the expansible chamber, but its release prevented. When the circuit is broken the ingress of the fluid under pressure is prevented and its egress is permitted. *F* shows the ingress port and *G* the egress port.

In the apparatus, as shown, the diameter of the opening in this secondary valve was $\frac{3}{100}$ths of one inch, and its lift was $\frac{4}{100}$ths of an inch, although even less would be sufficient. When air or other gas is used as the fluid under pressure, these dimensions are found amply sufficient, unless rapidity of action in the main valve is required when these dimensions are increased. From the smallness of area of secondary valve and its frictionless character, it will be seen that the electrical energy required to operate it is very small. Practically, one cell of gravity setting is found to be amply sufficient. The size of the secondary valve is not changed, although the primary valve be very large and worked under high pressures.

As actually shown, the fluid under pressure used was air. The apparatus exhibited consisted of a steam radiator for heating rooms, and having the diaphragm valve attached. A thermostat in the room controlled the electric circuit and thus the supply of steam. By this mutual reaction of the temperature and steam supply the temperature of the room remains constant. A large butterfly valve (eighteen inches in diameter), attached to an air flue, was also exhibited. This, likewise, was actuated by the thermal conditions of the room. Upon the boiler plant of the exhibition was placed a large whistle, actuated by this device. It is blown by touching a button in the superintendent's office. Other uses of this invention are included, such as the controlling of refrigerating machinery, steam pumps, elevators, rudders, etc.

This instrument was examined in its working and found to be entirely satisfactory. When the electric valve is used to control temperature a thermostat is employed. It consists of a thin long plate of hard rubber, and a similar one of steel, the two fastened together the entire length. The compound plate, thus made, is

fixed at one end while the other plays between two contacts which admit of easy setting within a narrow range. With a rise or fall of temperature, the thermostat curls and makes the contact, thus completing the circuit, on one side or the other, and regulates the valve. We found by experiment that the thermostat was quite sensitive and that the claim of the owners that the temperature could be controlled to a quarter of a degree each side of the setting point could probably be realized. We think, however, without having tested it, that the hard rubber plate of the thermostat would not work so well at high or low temperatures, as at the middle temperatures (65°—75°), but for housewarming and similar purposes, there will be no occasion to expose the instrument to such temperatures. The action of the thermostat is also quick. We reduced it from 64·5° to 32° in eight minutes.

The AUTOMATIC ELECTRIC HEAT REGULATOR.

MANUFACTURED BY THE PERFECT HATCHER COMPANY, ELMIRA, N. Y.

(F. ROSEBROOK, INVENTOR.)

The owners claim in their heat regulator, the combination of a double electric current, the electro-magnet, damper, door or valve, and suitable mechanism for operating dampers and valves.

The object of this invention is to provide means of regulating and controlling heating apparatus of any and every description, not only controlling the source of the heat, such as the combustion of coal, lamp flames, etc., but will also control the flow of the heat to different points. It consists of:

(1.) A thermostat, as shown in the accompanying cut on the left. This instrument is exceedingly delicate and sensitive, and will register the tenth part of a degree if so desired; this is hung in the room or apartment to be regulated, or controlled. If a room in a dwelling house, it can be placed on the wall in any convenient spot.

(2.) The motor connected with a damper or valve, as shown on right. This motor as shown, is a spring motor, but it can be of any form desired, or can be used in connection with a larger motive-power, such as water pressure, compressed air, etc. The essential object of this motor is to enable us to use two electric circuits, one to open the dampers and one to close the same, whereby we have a constantly open circuit, and a single cell will last in constant use for a year or more, with no other attention than to renew the water. This motor is provided with a circuit breaker (as shown at *T, U, V, Fig. 25.*), which breaks the circuit at a different point than the point of contact, the connecting wires across each other thereby keeping the surfaces always bright. No matter how much dust and dirt accumulate on this breaker, it never fails to respond promptly.

Any number of valves or dampers can be attached to this motor with proper increase of power.

(3.) The battery switch connecting wires.

Fig. 25 shows the thermostat on the left, and clock and valve on the right. The thermostat is hung on the walls of any of the rooms, as shown at *A*, *Fig. 26.* The clock-work and valve is placed on a branch of the smoke pipe of the furnace, as shown in *Fig. 26.* The electric jar is shown at *C*, in *Fig. 26.* The operation is

as follows: One must first decide upon what heat is most desirable, the majority prefer 72, others 68, 70, or even 80. Then move the pointer, *Fig. 27*, to the desired degree, as shown on the scale. For instance, if 70 is desired, move it to figure 70. The draft will be checked at 70 and put on again at 69, as the thermostatic bar is set for one degree variation, and is exceedingly sensitive to every variation of the heat; it is perfectly accurate, and responds to the variation more quickly than mercury. It is a compound bar of rubber and steel riveted tightly together. As the heat of the room rises, the unequal expansion of the two substances produces a

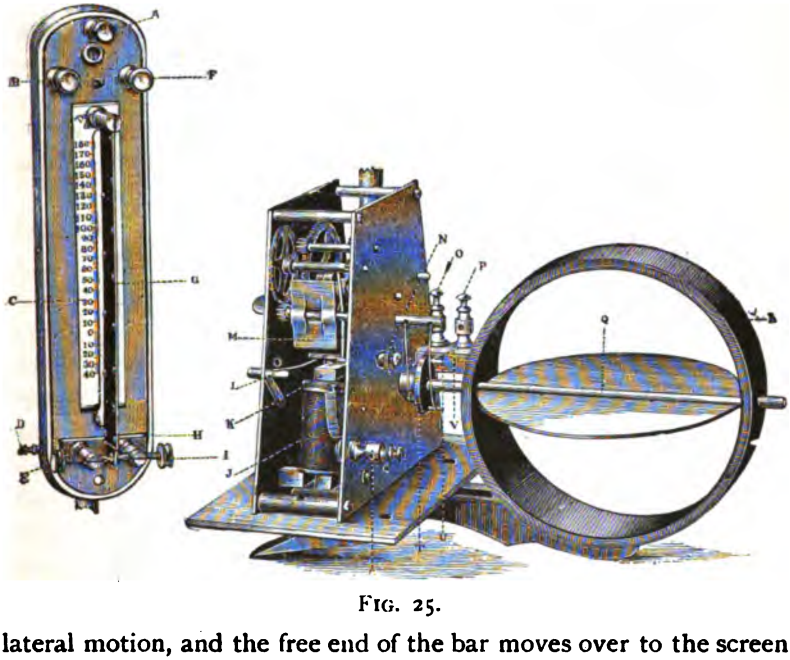


FIG. 25.

lateral motion, and the free end of the bar moves over to the screen *E*, and comes in contact with it, the electric circuit is closed. This sets the clock-work in motion, and the valve *F*, *Fig. 26*, opens, and the draft of the furnace is checked; the chimney, now drawing through this opening in the pipe, instead of through the furnace. Combustion of the coal practically ceases, and temperature moderately declines one degree and brings the bar *B* in contact with screw *F*. It is, therefore, easily understood that if the weather gets colder, more heat is required from the furnace, and the thermostat will not check the draft, until the heat is up to the right point, but

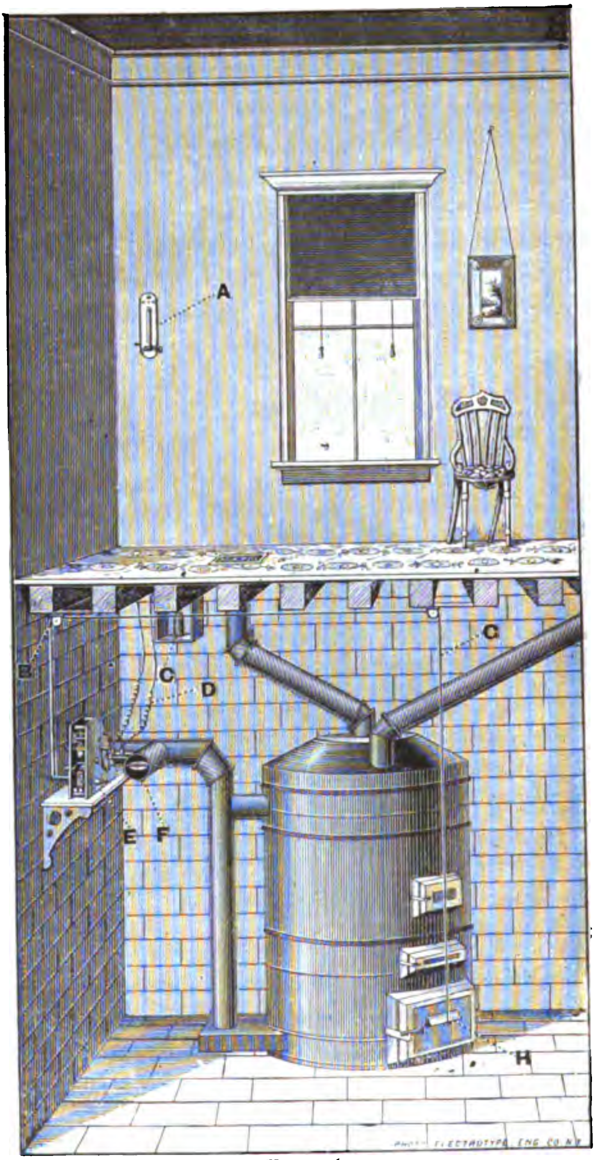


FIG. 26.

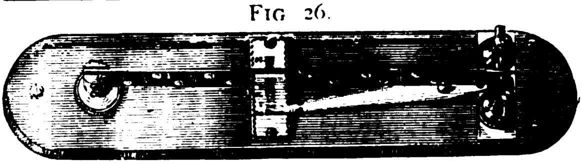


FIG. 27.

will drive it as hard as is necessary to keep the heat up, and per contra, if the weather grows warmer, the thermostat will hold the furnace in check and keep the heat down to the required point, thus checking all extra consumption and waste of coal; every pound of coal that is burned to raise the heat higher than is required, is wasted. It has been proven by actual experience in the past few years, that twenty-five per cent. of coal has been saved since adopting this regulator. The temperature can be changed instantly to any point desired by simply moving the pointer, *Fig. 27*, to the figure on the scale desired.

This regulator can be put to numerous uses, chief of which is its application to an incubator of the same makers, in which the motor operates a ventilator, in connection with the source of heat as well. In this case, the thermostat is altered and consists of a rubber rod stationary at one end, and connected with a lever delicately hung at the other, as the heat rises, this rod expands, throws the lever to one contact point, connecting a circuit, operating valves and lamps as the heat of the machine requires.

The above is part of the description of the instrument as made by the owners. The apparatus was of considerable interest, and some features of it deserve especial commendation. One of the thermostats is similar to that described in the preceding instrument, and has similar advantages and disadvantages. As in the preceding case, it is entirely suitable for any work likely to be required of it. The other thermostat is a rubber rod, by the expansion and contraction of which the necessary motive-power for the regulation of the valves is obtained. The character of its working can be judged from the study of the distribution of temperature in the incubator upon which Prof. Waldo is to report.

The contact breaker in this instrument deserves commendation. The contact is made on sliding surfaces, and the points of contact are thus kept smooth and bright.

STEAM VESSEL INDICATOR.

NOVELTY ELECTRIC WORKS, PHILADELPHIA.

This instrument is intended to inform the occupants of the pilot house of the position of the throttle and reversing levers in the engine-room. It consists (*Fig. 28*) of two parts, viz.: indicator and switches. The indicator proper, which is hung in pilot house has two electro-magnets and double armature, to which is attached

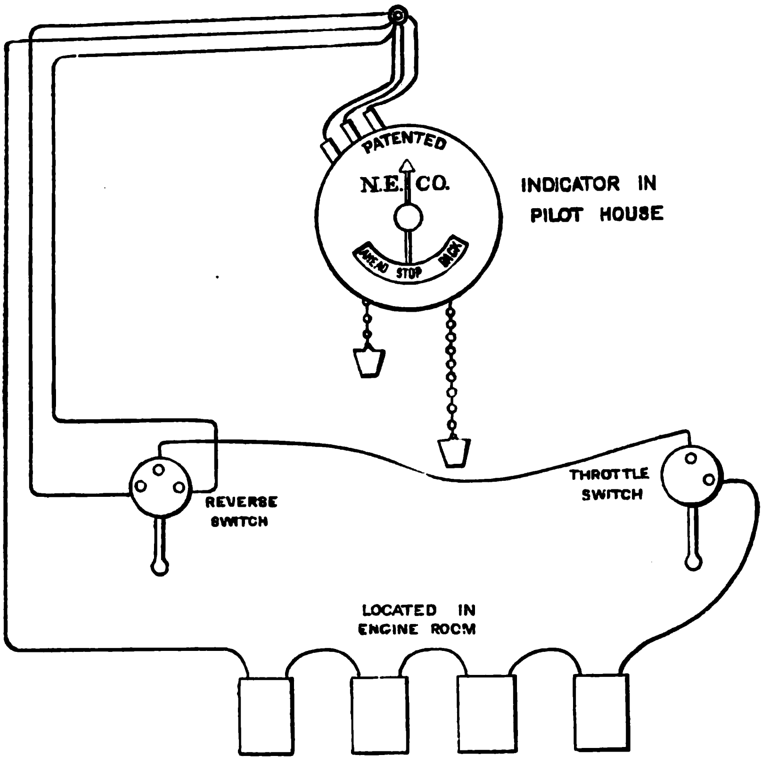


FIG. 28.

the indicating hand. As the current is thrown first through one magnet, and then the other, the needle indicates ahead or back. When the current is cut off, the needle points to "stop." The current is sent through one magnet or the other by means of the switches, which are connected to the levers of the engine; one to the throttle, the other to the reverse. The mode of operation is very simple, consequently reliable When the pilot rings the bell

to move, the moment the engineer touches the lever of the engine, it shows in the pilot house which way the reverse lever is standing, as the current must flow through one of the two magnets. When the engineer reverses the engine, he cuts the electric current from one magnet and causes it to flow through the other, thus causing the armature to be attracted one way or the other, indicating either ahead or back. The starting lever starts the electric current.

The reversing lever shows which way the engine will move. The general relations of the parts are shown in the accompanying diagram. When not required, the circuit can be opened and so left until again required, the change from open to closed being made in the pilot house by the cords suspended from the dial. The circuit is also broken when both levers are undisturbed, in which case the index swings by its own weight to the mark "stop." A bell is connected with one circuit, so that the position of the engine levers is also distinguished by the ear. The indicator seems to be effective and reliable.

TELEMETERS.

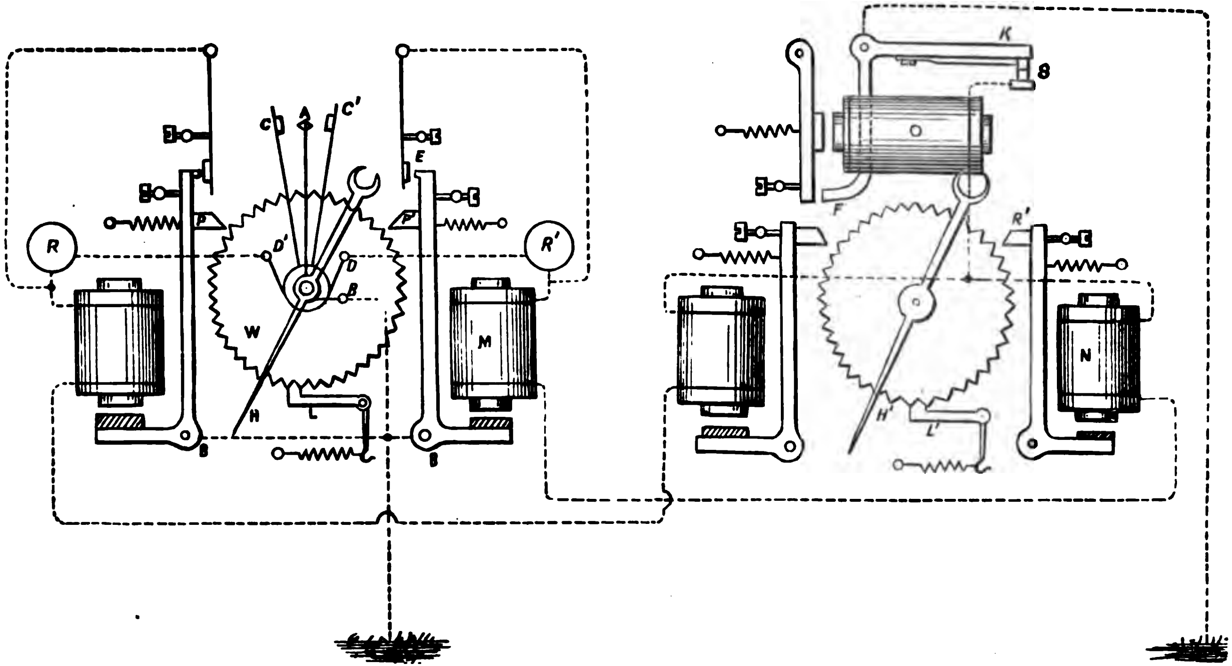
THE TELEMETER COMPANY, NEW YORK CITY.

This is a complete and novel system of transmitting and recording physical changes at a distance and continuously. As exhibited, the system was applied to temperature and atmospheric, steam and water pressure, but the system admits of indefinitely extended application. The Telemeter Company attributes the system to Robert Hewitt, Jr., as originator, and to Charles L. Clarke, as inventor.

The novel part of the system is the transmitting device and receiver. The following description of them is Mr. Clarke's: (*See Plate XII.*)

The transmitting device is at the left hand, and receiver at the right hand.

The contact arm *A* is on a shaft, and is moved by the initial physical instrument, be it metallic thermometer, barometer, pressure gauge, float or other device. It is not insulated from the metal frame of the instrument, and is therefore connected (electrically) to the *base*, as are also the armature levers. This fact is shown diagramatically at *B B B*, and by the circuit connecting the three points. *C C′* are two contact points carried on arms, which are carried on an insulated sleeve, and also insulated from each other. This sleeve is carried on a shaft (which also carries the V-toothed wheel *W*) which is in line with the shaft carrying *A*. As *W* revolves with *C C′*, the continuity of the circuit is preserved by two insulated posts, *D D′*, which carry two wires resting in two grooves in the insulated sleeve, thus maintaining the circuit of *D* with *C*, and *D′* with *C′*, respectively. The shaft carrying *W*, *C C′* also carries the index hand *H*. *P P′* are the pawls which propel the wheel *W*, are normally out of the path of its teeth, the wheel being held by the locking pawl <. When *P* advances, it engages at tooth near its point, and pushes it ahead until the pawl rests in the space between the teeth which it fits. In this position, the under face of the pawl is a tangent to the circle of which the pivot on which the armature lever revolves in the centre. Hence, the face of the tooth pushes dead against the centre, and no force such as the momentum of the wheel, resulting from the force of the blow given by the pawl, can disengage the pawl. Therefore, no matter what the excess of battery-power, the wheel can never be



System of the Telemeter Company.

revolved the distance of more than one tooth by a single impulse, and the whole constitutes a complete locking device. When the pawl P has reached the limit of its forward movement, the pawl $<$ has slipped over the point of its next tooth, so that when P is withdrawn it $<$ slips into the space and completes the motion of the wheel, which is the amount of one tooth. The wheel and pawls of the receiver are similar to those of the transmitter, hence if both instruments receive a full impulse, sufficient to carry P to its forward limit, they must move in unison, as neither wheel can move more than a tooth for a single impulse. When A is moved by a force and touches C, the magnets N, N, O are in circuit, as also the small resistance coil R'. N is so adjusted that it attracts its armature first. The first movement of its armature causes a contact at E, which forms a shunt around resistance R' and contact A C. The continued motion of the armature causes P' to engage a tooth and to turn the wheel W until P' fits in the space between the teeth, thus locking the wheel, and separating the contact A C, the pawl $<$ also slipping over the point of its next tooth. The circuit has not been broken, because a shunt was formed around A C before they were separated. They were also separated without a spark, because they formed a branch circuit with R' resistance to a shunt with no resistance. Simultaneously, or nearly so, with the engagement of P', the pawl R' in the receiver also engages the wheel, and the operation last described is repeated here. The magnet O is adjusted to respond last in the series, and the movement of its armature lever strikes the arm F, thus throwing up the horizontal arm F, and breaking the circuit at S. The instant that S is opened, the spring draws the armature levers back to their normal position, separating the points at S, and since A C are already open, when S closes again on its return stroke, the circuit is open and remains so until A makes another contact. Also the return of the armature levers disengages P' and R', and permits $<$ $<'$ to complete the movement of one tooth, and H H' have moved one division on the dial. The spark is all transferred from the delicate contacts to the rough, large, non-adjustable contact S.

It is impossible for H H' to move except in unison, because any current will first firmly close the circuit at R, and the circuit cannot open until O operates, and this is adjusted to work last.

To prevent S from opening at the wrong time (which it could do from a mechanical jar or shock, thus, perhaps, opening after H had moved, and before the movement of H', thus throwing the hands H H, out of unison) the point S carried by K is supported on a long spring, which is so adjusted that when K is raised S is held about $\frac{1}{14}$th inch from K, but when K is down S presses against it. Thus, any jar which may raise E less than $\frac{1}{14}$th inch does not cause S to break the contact. (*See Fig. 29.*)

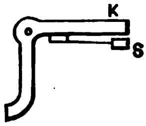


FIG. 29.

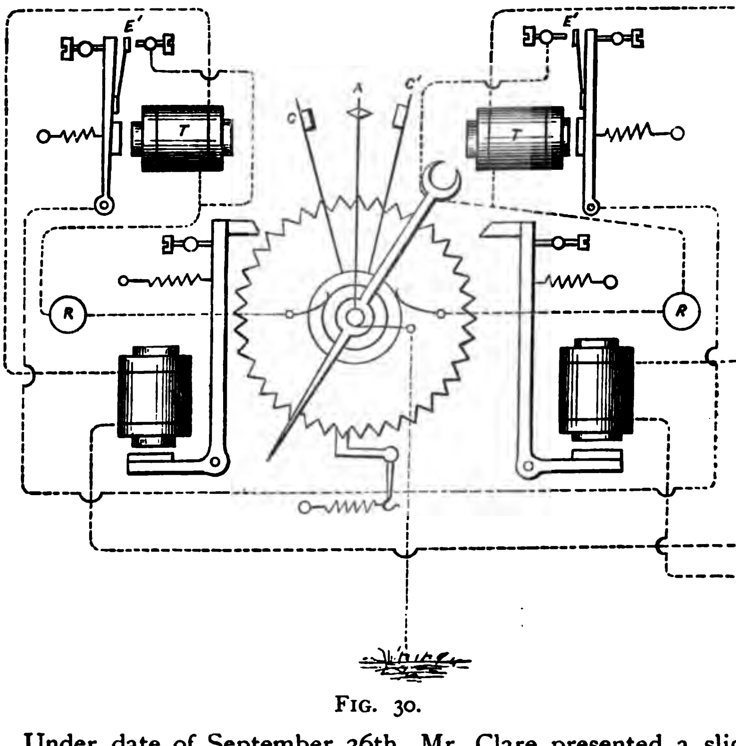


FIG. 30.

Under date of September 26th, Mr. Clare presented a slight modification of the apparatus, with a transmitter, in which the shunting around the primary contacts A C C' is accomplished by magnets T T at E' E'. The latter method presents some advantages over the preceding. (*See Fig. 30.*)

The actuating instrument for the telethermometer is a metallic thermometer made by the Standard Thermometer Co. of Pea-

body, Mass. In accompanying *Fig. 31*, the base plate *A* carries a port *B* through which passes a stud *C*, which is fastened firmly by a set screw *D*. The stud *C* supports an arm, and to it is rigidly attached one end of the bi-metallic spiral *G G* by the set screw *F*.

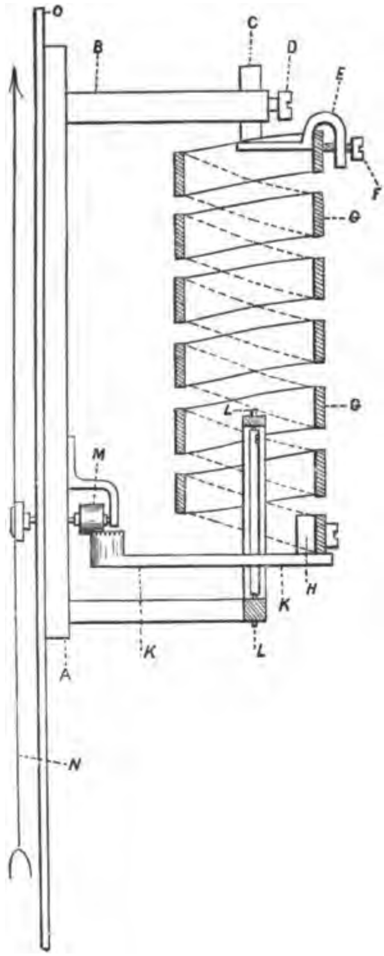


FIG. 31.

The range of the thermometer is adjusted by changing the length of *G* as chamfered on *E*. The spiral *G* is made of two metals, having different coefficients of expansion. One end is fixed at *E*, and the other end is free to move as the rise or fall of temperature lengthen or shorten the spiral circumferentially. The end free to

move is attached at H to a segment of a crown wheel $K K$. $K K$ revolves on its bearings $L L$, and moves the pinion, M, carrying the index arm or pointer N in front of a graduated dial O, indicating upon this dial the temperature which affects the spiral $G G$.

The work which can be got from a metallic thermometer well constructed, is of considerable interest, and the sub-committee made a special test of some of the instruments provided by the Telemeter Company. The test was under Dr. Waldo's direction and his report will follow.*

The telemanometer is actuated by a Bourdon tube; the telehydrobarometer by a wheel and float on a mercury column balanced by water pressure. The telebarometer is actuated by a wheel and float in the open arm of a siphon barometer of large diameter, to prevent error from capillarity. The telemeter instruments are recording, the paper being moved by clock-work. Maximum and minimum alarm hands are also provided, which may be set at will to ring an electric bell at any desired limits. By the use of a polarized relay and batteries of opposite polarity, one wire connecting the two instruments may be dispensed with.

The committee examined this exhibit with interest and attention. The general system is good, and the minor intrinsic difficulties have been successfully overcome by the inventor.

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* These thermometers have since been studied by Professor Rogers, who published his results in the *Am. Meteorological Journal*, Vol. II., pp. 252–257.
H.

REPORT OF SUB-COMMITTEE ON TIME-PIECES.

EXHIBIT OF THE TIME TELEGRAPH COMPANY, OF NEW YORK.

This company had a large exhibit, which was scattered over the buildings. The particulars to which they wished to call especial attention were as follows, as made out by Mr. H. L. Bailey, their electrician :

(1.) An electrical pendulum regulator. The pendulum of which is subject to uniform impulses, with a minimum of friction or variation, the electrical contacts of which are absolutely certain in their performance, and at which there is a complete suppression of spark, while operating the circuit, the latter being accomplished by placing a non-inductive shunt of fifty ohms resistance around magnets of ten ohms resistance in the circuit. The perfection of the driving anchor, which corresponds to the escapement of non-electric clocks. The ratchet wheel, which prevents any backward movement of the scape wheel.

The device by which the train effects the contacts for minute and second dials, whereby the pendulum suffers no disturbance, and notice taken of the fact that variation of friction in the train, or variations in the strength of the actuating current, uniformity of action, and its adaptability to the purpose for which it is used.

(2.) A system of sparkless circuit closers for the operation of secondary electrical clocks or other electrical devices. Its operation depending upon the automatic introduction of shunt around the magnetic circuit, before opening the battery circuit.

(3.) Secondary electric clocks. One known as Crane's dial movement, in which the driven wheel is perfectly locked in either open or closed circuit. It is simple and perfectly reliable in its action.

(4.) Secondary electric clock, "Gray's dial" with its double motion, first radial then tangential, also thoroughly reliable in its performance.

(5.) Exhibit of three or four other dial movements, controlled by the Time Telegraph Company.

(6.) A table half-second pendulum clock, device of C. H. Pond.

(7.) A system of synchronizing pendulums, without any harness being applied to the pendulum of the primary regulator, but, making use of the electrical seconds, furnished by the rocking armature table of the electric regulator.

The requirements of the Time Telegraph Company and the engagements of the committee necessitated putting this examination in the hands of Professors Rogers and Harrington. The exhibition was not a suitable place for critical tests of such delicate mechanisms; such tests require also considerable time; the subcommittee therefore decided to, in some sort, integrate the entire system by directing attention to the actual time keeping capacity of the system and of the controlling clock. This was done by sealing the various accessible secondaries, and leaving them so for several days, and also by comparing the controlling clock with time received from Washington. These tests were begun by the two members of the committee, but completed by Prof. Rogers, whose report is incorporated here:

REPORT ON THE PERFORMANCE OF THE STANDARD ELECTRIC CLOCK, EXHIBITED BY THE TIME TELEGRAPH COMPANY.

The master clock, which controlled the dials exhibited by this company, was mounted upon a wooden pier, fairly insulated from the building. Two other clocks, of similar construction, were mounted upon the same pier, one of them being upon the opposite face.

It is still an open question whether an electric clock can be regarded as an instrument of precision, even when mounted under the most favorable conditions. It certainly was not to be expected that the performance of this clock should be exceptionally good, especially as there was a weaving loom in the space occupied by an adjacent exhibitor. It will be seen, however, that the clock maintained a nearly constant rate between October 4th and October 9th.

The comparisons with the clock at the central office, from which the Washington time is distributed, were made by means of a chronograph, kindly placed at my disposal by Capt. O. E. Michaelis, in charge of the exhibit of the War Department.

The sounder through which the time signals were received, was connected with the master clock in such a way that only eight or ten of the first seconds of each minute were given for the central clock, and only the beginning of each minute for the master clock.

In the transcript of the chronograph sheet given herewith, the long stroke, *a*, *b*, represents the beginning of the minute of the master clock, the initial point being at *a*. The beginning of the minute of the clock at the central station is indicated by the break *c* (*Fig 32*).

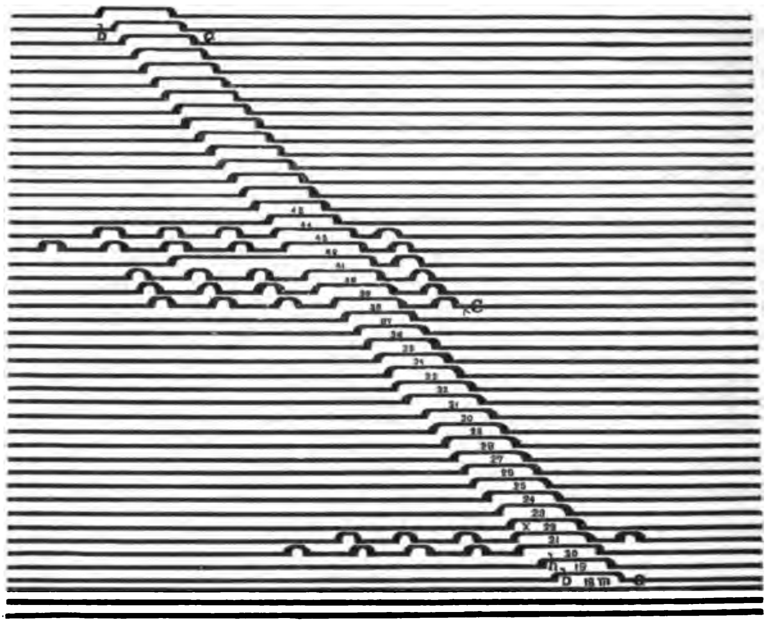

FIG. 32. Section of Chronograph Sheet, Comparison of Clocks.

The corrections of the Washington signals were kindly communicated by Lieut. C. C. Pendleton, of the Naval Observatory. These corrections combined with the observed deviations from the Washington signals at the central office, give the following corrections to the central clock at 12 *h*. M.:

October	*s.*	*October*	*s.*
4,	— 0·5	7,	— 1·6
5,	— 0·4	8,	— 1·6
6,	— 0·8	9,	— 1·8

Comparison of Master Clock with the Clock at Central Office:

October 4th. Master Clock Slow.

h. m.	s.
12 36 P.M.	+ 0·63
1 11	0·61
2 18	0·64
2 30	0·62
4 53	0·64
1 38	0·65
9 42	0·62
	+ 0·63
	— 0·50
	+ 0·13

October 5th. Master Clock Slow.

h. m.	s.
6 46 A.M.	+ 0·57
12 00 M.	0·55
1 00 P.M.	0·53
2 00	0·54
3 00	0·57
5 00	0·58
7 00	0·58
9 00	0·54
10 45	0·57
	+ 0·56
	— 0·40
	+ 0·16

October 6th. Master Clock Slow.

h. m.	s.	h. m.	s.
6 47 A.M.	+ 0·45	8 3	+ 0·78
7 40	0·49	9 45	0·90
9 00	0·46	10 20	0·87
10 50	0·53	11 00	0·91
11 27	0·54		
12 22 P.M.	0·54		+ 0·66
5 56	0·68		— ·80
6 22	0·69		
6 41	0·71		— ·14

October 7th. Master Clock Slow.

h. m.	s.
6 50 A.M.	+ 1·54
8 10	+ 1·57
8 50	+ 1·54
1 00 P.M.	+ 1·55
2 30	+ 1·59
5 50	+ 1·73
6 15	+ 1·74
6 40	+ 1·77
7 00	+ 1·79
7 40	+ 1·81
8 00	+ 1·78
8 30	+ 1·80
	+ 1·68
	— 1·60
	+ ·08

October 8th. Master Clock Slow.

h. m.	s.
7 10 A.M.	+ 1·86
7 30	+ 1·88
9 47	+ 1·88
2 30 P.M.	+ 1·89
	+ 1·88
	— 1·60
	+ ·28

October 9th. Master Clock Slow.

h. m.	s.
7 10 A.M.	+ 1·86
9 45	+ 1·87
10 00	+ 1·88
	+ 1·87
	— 1·80
	+ ·07

In tabulated form, the corrections of the master clock are nearly as follows, at 12 *h.* M.:

October	s.	October	s.
4,	+ 0·13	7,	+ 0·08
5,	+ 0·16	8,	+ 0·28
6,	— 0·14	9,	+ 0·07

Since the probable error of a single estimation of the deviation of the central clock from the Washington signals is at least, 0·2 *s.*, the resulting corrections for the master clock came out quite as small as one should expect. The slight increase of the correc-

tions shown by the afternoon comparisons are probably due to the tremors produced by the loom, which was then generally in operation.

The synchronism by which the three clocks maintained the same rate was in this instance more marked than the writer has ever before witnessed. At no time during the exhibition did they differ much in excess of 0·5 *s.* In order to be able to estimate the amount by which the master clock could be changed through synchronism, a weight of thirty-one grammes was added to the pendulum opposite the master clock at 10 *h.* 0 *m.*, October 9th. At this time the deviation of the master clock was 1·87 *s.*

The following relations were subsequently found:

Time of Comparison. *h.*	*m.*	*Master Clock Slow of Central Clock.* *s.*
2	30	+2·20
3	30	2·40
4	30	2·52
6	50	2·54
7	20	2·52
9	00	2·46
10	00	2·52

At 10 *h.* 1 *m.* the added weight was removed. By the next morning, the error of the clock had been reduced to the previous value, 1·9 *s.* It is to be regretted that there was not sufficient time for a repetition of this interesting experiment. W. A. R.

On the Performance of the Electric Clock Exhibited, Controlled by the Master Clock

This clock was located about 200 feet from the master clock. Every comparison of the two clocks, made previous to October 4th, showed an exact coincidence within the limits of the error of comparison, which may perhaps have amounted to 0·2 *s.* At 4 *h.* 30 *m.* P. M., October 4th, the control was removed.

Subsequent comparisons gave:

Date. October	*Time.* *h.*	*m.*	*Controlled Clock fast.* *s.*	*Reduced to 9 h. 20 m., Oct. 4th, with Hourly Change — ·962 s.* *s.*	*Sum.* *s.*
4,	9	20 P. M.	= — 4·0	+ 0·0	— 4·0
5,	9	20 A. M.	= — 16·2	+ 11·5	— 4·7
6,	7	00 A. M.	= — 36·4	+ 32·4	— 4·0
6,	4	50 P. M.	= — 46·8	+ 41·8	— 5·0
7,	5	43 P. M.	= — 69·8	+ 65·8	— 4.0

It appears, therefore, that the controlled clock maintained an approximately constant rate after the removal of the control. The clock was now set 1 *s*. slow. At the end of 18·2 hours, it had gained 18·8 *s*., giving an hourly rate of 1·03 *s*. At 10 *h*. 5 *m*., the magnet was held 18 *s*. leaving the clock 1·0 *s*. slow. October 9th, at 10 *h*. 44 *m*. A. M., the correction was 1·3 *s*. slow. It appears, therefore, from these observations that the control is practically perfect.

In order to determine the magnitude of the rate which could be overcome by the control, 92·4 grammes were added to the pendulum. The following comparisons were then made:

Date. October	*Time.* *h.*	*m.*	*Clock Slow of Master Clock.* *s.*	
9,	11	30 A. M.	1·1	
9,	12	15 A. M.	1·1	
9,	12	40 A. M.	0·8	At 2 *h*. 5 *m*. added 24 grammes.
9,	2	5 P. M.	0·8	At 2 *h*. 6 *m*. took off control.
9,	10	8 P. M.	28·5	Fast.

The hourly change, therefore, with the weight added, is 3·64 *s*., giving 2·5 *s*. for the rate due to the weight alone.

It appears, therefore, that the control will overcome a gaining rate of about 3 *s*. per hour. Lack of time prevented further observations in this direction. W. A. R.

Report on the Performance of the Time Dials.

The somewhat laborious operation of sealing the dials by covering the faces with threads, sealed in such a manner as to effectually prevent their being opened by unauthorized persons, was completed under the direction of Professor Harrington during the afternoon of October 7th. The dials were examined twice each day till the close of the exhibition. On account of my absence on the closing day, the examination was kindly made by Professor J. Burkitt Webb.

The number of dials in the circuit was sixty. In justice to the exhibitor, it should be stated that it was not expected that the performance of two of this number would be satisfactory on account of their locations. One was located above the bridge, connecting the two buildings, and the other was placed in the headquarters of the Board of Examiners.

The former clock, upon one occasion, lost two seconds, and the latter stopped upon three occasions. Another dial stopped within

a few minutes after the trial had begun from some unknown cause. With these exceptions, the coincidence of beats was exact in every case when the seals were broken at the close of the exhibition.

W. A. R.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXII.

(*SECTION IV—A, CLASSES V, VI, VII OF THE CATALOGUE.*)

Supplementary Report on Meteorological and other Registers.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

REPORT OF DR. LEONARD WALDO ON THE UNIFORMITY OF TEMPERATURE MAINTAINED IN THE INCUBATOR EXHIBITED BY THE PERFECT HATCHER COMPANY, OF ELMIRA, N. Y.

NEW HAVEN, September 1, 1885.

PROFESSOR M. W. HARRINGTON, *Chairman of Sub-Committee, Section XXII, on "Self-Registering Instruments."*

SIR:—I submit herewith my report on the steadiness of temperature maintained in the incubator exhibited by the Perfect Hatcher Company, of Elmira, N. Y.

Respectfully yours,

LEONARD WALDO.

REPORT.

For many purposes in physical science as well as in the arts, it is desirable to maintain approximate uniformity of temperature for considerable periods of time. It seemed probable from a superficial examination of the incubator exhibited by the Perfect Hatcher Company, of Elmira, N. Y., that a large measure of success had been attained by them. This instrument therefore received more careful consideration by your committee than would otherwise have been given to it. The following description and diagrams of the method of working is furnished by the makers:

In *Fig. 1*, there is a dead air space between top of tank E^2 and wood casing. The tank containing water is covered with a series of layers of paper, say twelve to twenty; then a solid building paper; then a frame work one inch thick to separate the walls of paper; then a layer of solid building paper next the wood cover. This forms a dead air space of one inch in thickness, besides the protecting walls. The object is to prevent the radiation of the heat from surface of tank upwards, and to cause it to deflect to egg chamber below; and it is claimed that this is effectually accomplished by this method. The cubic contents of air chambers are 6,468 inches. The outlet for the hot air was a valve 3 x 12 inches. The inlets for fresh air were four in number, and were 2 x 4½ inches. The openings in this test were 1 x 2½ inches, four in number. At every opening of the large valve, 3 x 12, on top of machine, the lamp flame was de-

creased to stop heating of water, and was restored to full flame when this valve was closed. The method of applying heat is by a kerosene oil lamp flame or gas flame. This flame heats water in the

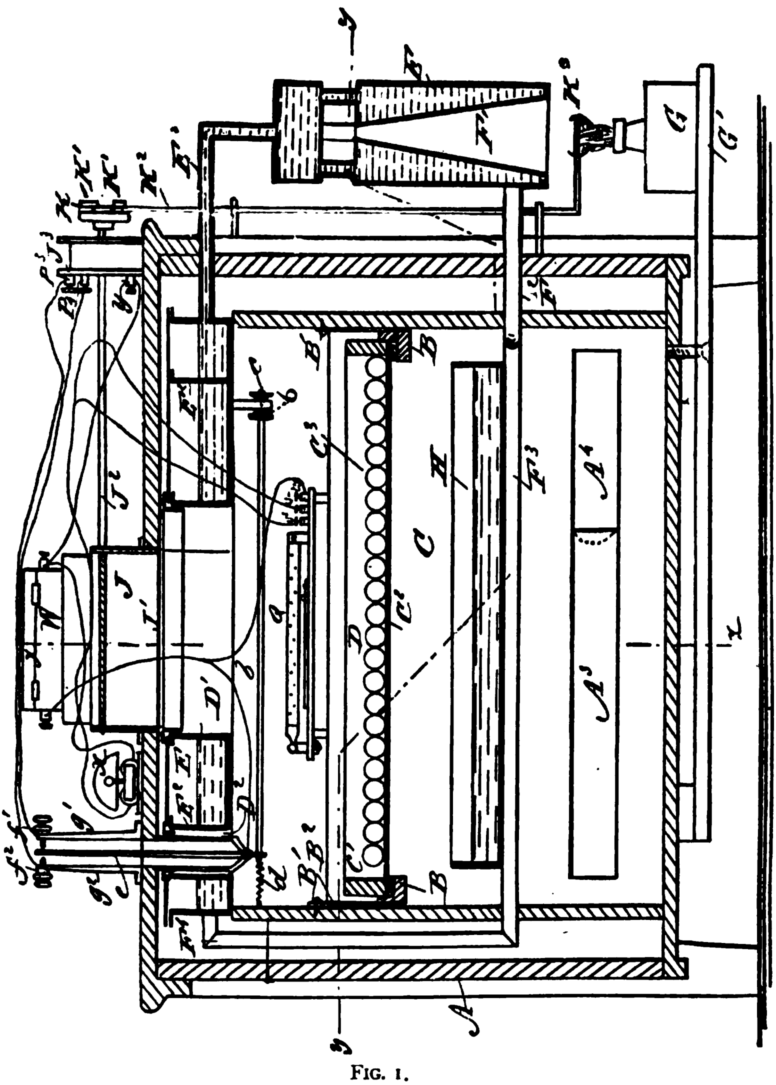

FIG. 1.

boiler, which circulates through tank and pipes in such a manner that the heat is evenly distributed throughout the chamber to be heated, etc.

PHILOSOPHY OF ITS OPERATION.

Fig. 1 shows a sectional view of the hatcher and all its working parts. On the right end is the boiler, F^1; under it the lamp G. Covering the entire top of the machine is the water tank, E^2; the water is heated in the boiler, E, passes through the tank in a series of channels, then out and down through pipes F^4 and F^3 back to boiler again to be re-heated. On top of these pipes are the open pans of water; the evaporation from these pans is in proportion to the heat furnished by the pipes—the hotter the pipes are, the more rapid the evaporation from the pans.

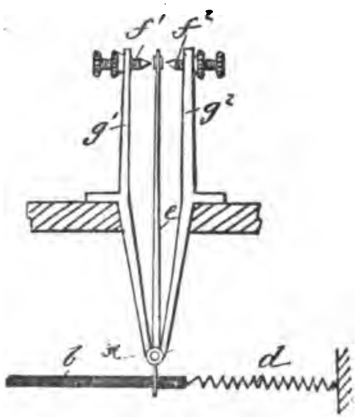

FIG. 2.

The heat is regulated automatically, as follows:

The rod b is hung rigidly at the right end, and firmly held in bracket by nuts c and 6; the end at left is attached to bottom of lever e; this lever is hung on the points of two screws, carefully adjusted so that the lever is perfectly free in its action. See also *Fig. 2*. This rod is exceedingly sensitive, to every variation of heat, expanding and contracting lengthwise with one-quarter of a degree variation. As it expands with the heat, it throws top of lever over towards regulating screw f^1 (see *Figs. 1* and *2*.) and as it contracts it throws the point of lever over against screw f^2. Whenever this lever comes in contact with either screw, it closes the electric circuit which causes the magnets L^3, *Fig. 3*, to pull down the armature L^2, which releases the fly pin M, *Fig 4*, and allows a quarter revolution of the clock, which opens or closes ventilators and turns up and down the lamp flame. When lever e comes in

contact with screw F^1, it causes ventilators to open and lamp flame to turn down, thus completely checking the heat, and when contact is made with screw F^2 the reverse takes place and heat is restored.

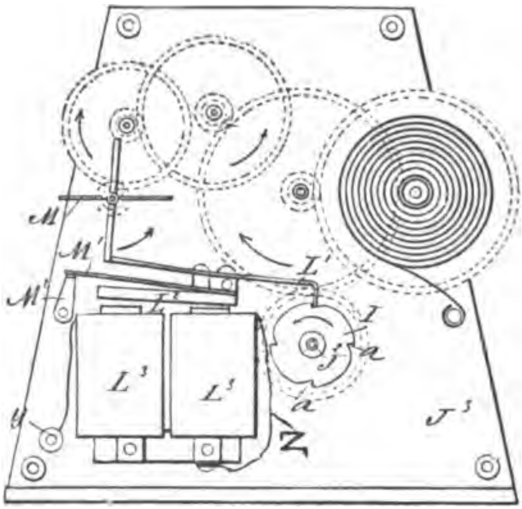

FIG. 3.

Your committee began the test for temperature steadiness on the morning of Thursday, October 2, 1884. There were present Messrs. M. W. Harrington, W. A. Rogers, and the writer. Two thermometers were attached to the rubber bar thermometer *2*, indicated in *Fig. 1*, whose errors did not exceed ·1° F., and whose bulbs were of thin glass and quite sensitive to changes of temperature. The water in the incubator had been exposed to the action of the kerosene lamp for several hours, and the temperature had risen to 105°, or thereabouts. Your committee requested the attendant to set the indicator to maintain a temperature of 101°.

The mercurial thermometers, which may be called III and II for brevity, read as follows during this part of the trial:

Date and Hour, 1885.	Committee Thermometer III.	Condition of Incubator.
October 2d, A. M.		
h. m.	degrees.	
9 58·5	105·4	Automatically lowering its temperature to 101° at the request of the committee.
10 12·7	103·8	
10 21·0	102·6	
10 30·3	101·[illegible]	

The set screws between which the indicator plays to make and break the circuit operating the clock-work were then set by the attendant; the entire apparatus was then tied by the committee with cotton lamp wicking, and sealed in such a way that the lamp, or any part of the apparatus, could not be changed without breaking the seals, except by the self-acting regulating apparatus, and the following observations made:

October 2, 1884.	Committee Thermometer III.	Committee Thermometer II.	Condition of the Incubator.
A. M.			
h. m.	degrees.	degrees.	
10 30·3	101·7	101·1	Automatically keeping its temperature uniform.
10 45	101·6	100·9	
11 11	101·6	100·9	
11 32	101·6	100·9	
11 45	101·6	101·0	
P. M.			
12 50	101·3	100·5	
1 47	101·5	100·9	

During the preceding observations, a change of about ·1° F. in the reading of the thermometers was followed by the operation of the ventilating fans of the incubator. The opening and closing of these fans took place at intervals varying from one-half minute to two minutes, continuously throughout the trial. Your committee then broke the seals and requested the attendant to increase the temperature to about 109°. This being done, the following readings were made during the afternoon and the succeeding morning, when the seals were finally removed.

1884. October 3d and 4th.	Committee Thermometer III.	Condition of the Incubator.
October 3d. P. M.		
h. m.	degrees.	
2 49	109·5	Automatically keeping its temperature uniform.
3 47	109·0	
9 12	108·5	
October 4th, A. M.		
8 33	109·1	
8 37	109·1	

October 4th, 8·40 A. M., temperature of the outside air, 62° F.

The above observations speak for themselves, and your committee is of the opinion that the apparatus as exhibited and with careful adjustment will maintain a uniform temperature to within $\frac{1}{4}$° F., when the temperature in the incubator is higher than that of the surrounding air.

Respectfully submitted,

LEONARD WALDO, *Sub-Committee.*

REPORT OF DR. LEONARD WALDO, SUB-COMMITTEE OF SECTION XXII, ON THE EXHIBIT OF METALLIC THERMOMETERS MADE BY THE STANDARD THERMOMETER COMPANY, OF PEABODY, MASS.

NEW HAVEN, September 1, 1885.

PROFESSOR M. W. HARRINGTON, *Chairman of Sub-Committee on Registering Meteorological Instruments, Section XXII.*

SIR:—I submit herewith my report to you on the exhibit of the Standard Thermometer Company, of Peabody, Mass., made at your request.

Very respectfully yours,

LEONARD WALDO.

REPORT.

The limitations of mercurial and other thermometers are felt in many of the processes of the arts. The boiling and freezing points of mercury being so near together, and the nature of glass rendering it so fragile, and so liable to softening near the boiling point of mercury, combine to render some substitute for the mercurial thermometer highly desirable in many cases.

Your committee, therefore, with your consent, decided to give as thorough an examination into the performance of the metallic thermometers exhibited, as the limits of an extemporized laboratory would allow.

The exhibited thermometers consisted essentially of a coiled cylindrical spiral, the material of which was composed of laminated brass and steel, united by silver solder.

This cylindrical coil is about 1·5 inches long, about ·6 of an inch in diameter, each coil having a width of ·1 inch, and making about twelve turns throughout its length. A change of temperature will, of course, cause an extension of a free end of such a coil, and this extension is magnified by a rack and pinion, which gears the indicator to the free end of the coil.

As constructed by this company, the apparatus is simple, the adjustment of the hand which serves as an indicator, and which moves over a circular dial, is easily effected, and your committee is of the opinion that the indications would be consistent with themselves permanently, so far as liability to get out of adjustment is concerned.

The hand which serves as the temperature indicator, moves over a clearly graduated dial, and the entire instrument is cased in a metallic box, and made to hang in any position.

Two metallic thermometers were selected for careful examination; they were marked Nos. 22 and 23. The hands moved over the dials smoothly, without hitching and in the open air had the usual agreement with mercurial thermometers hung in neighboring positions which is expected of reputable mercurial thermometers.

A water-comparator consisting of a rectangular box holding several gallons of water and provided with heating and stirring arrangements was rigged up in a neighboring building, and the two metallic thermometers were immersed in the water in connection with a number of precision thermometers. After a thorough agitation of the water, the thermometers were read in such a series that the observer began at the left hand end of the row of thermometers standing in the comparator and read to the extreme right. Then making a second reading at the extreme right, the thermometers were then read in an inverse order. The times at the beginning and end of the entire series being noted and the intervals between the readings of the thermometers being practically the same, it is assumed that the means of the thermometer readings correspond to the mean of the observed times.

This is not rigorously true, since the radiation coefficient of the comparator and of the thermometer is not taken into account. Its accuracy is in keeping with the general accuracy to be attained in such apparatus as we were able to devise during the exhibition. Professor Harrington made the record, and occasionally verified the thermometer readings. Professor Rogers was present during a part of the test.

The standard thermometers inserted in the comparator consisted of two short standards made by Hicks, of London, graduated to ½° Fahrenheit, 1° F. = 1·8 mm. The first thermometer of the two reading up to + 40° F., and the second reading to + 103° F.

The corrections of these standards were determined by comparison with the Yale College Observatory standards to be at

Degrees F.	*Degrees F.*
32	0·0
52	0·0
72	+ 0·1
92	0·0

A third standard introduced was one of the standards issued by the Yale Observatory, graduated in C. degrees to $\frac{1}{5}$° C., and having 1° = 4·7 mm. It is marked "Yale Observatory Standard 53.," and I am indebted to Mr. O. T. Sherman, of the Yale Observatory Thermometric Bureau, for the following system of corrections to be applied to its scale.

Degrees C.	*Degrees C.*
0	— 0·04
5	— 0·007
10	+ 0·043
15	+ 0.028
20	+ 0·016
25	+ 0·025
30	+ 0·073
35	+ 0·130
40	+ 0·074

The following observations were made:

Observed Readings of the Standard Mercurial Thermometers: "W. O. I.," "W. O. II.," "Y. O. 53," in a Water Comparator with the Metallic Thermometers marked "No. 22" and "No. 23."

	Date and Time of Comparison.	Reading of W. O. I.	Reading of W. O. II.	Reading of Y. O. 53. (Centigrade.)	Reading of No. 23.	Reading of No. 22.	Y. O. 53, reduced to Fahr.	Y. O. 53, correction in Fahr. degrees.	W. O. I. and W. O. II., correction.
	1885. October 3d.								
	h m.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.	degrees.
1	12 47·8	26·9	. . .	— 2·55	27·8	27·0	27·41	. . .	. . .
	12 51·1	27·1	. . .	— 2·50	27 8	27·1	27·50	— 0·06	0·0
2	12 53·4	27·05	. . .	— 2·60	27·9	27·1	27·32	. . .	. . .
	12 56 9	27·15	. . .	— 2·60	27 9	27·1	27 32	. . .	. . .
3	12 58·8	27·15	. . .	— 2·50	28·1	27·3	27·50	. . .	. . .
	1 2·2	27·35	. . .	[— 2·20]	28·2	27·3	[28·04]	. . .	. . .
4	1 3·8	27·4	. . .	— 2·40	28·2	27·6	27 68	. . .	. . .
	1 7·2	27·5	. . .	— 2·40	28·2	27·6	27·68	. . .	. . .
5	1 10·4	27·6	. . .	— 2·15	28·3	27·6	28·13	. . .	. . .
	1 14·2	27·55	. . .	— 2·35	28·3	27·6	27·7	. . .	. . .
6	1 35·9	. . .	38·25	+ 3·55	39·20	38·70	38·39	. . .	. . .
	1 39·7	. . .	38·38	+ 3·60	39·20	38·70	38·48	+ 0 08	0·0
7	2 5·1	. . .	68·80	20·40	70·5	68·9	68·72	. . .	. . .
	2 10·2	. . .	68·70	20·40	70·6	68·9	68·72	+ 0·03	+ 0·1
8	2 16·5	. . .	68·60	20·34	70·3	68·7	68·59	. . .	. . .
	2 20·1	. . .	68·55	20·30	70 3	68·7	68·54	. . .	. . .
9	4 11·9	. . .	89·40	31·65	91·9	89·0	88·97	. . .	. . .
	4 14·7	. . .	89·10	31·60	91·9	89·0	88 88	+ 0·13	0·0
10	4 15·2	. . .	89 10	31·60	91·9	89·0	88·88	. . .	. . .
	4 18·5	. . .	89·05	31 55	91·9	89·0	88·79	. . .	. . .
11	4 19·0	. . .	89·00	31·53	91·9	89·0	88·75	. . .	. . .
	4 20·3	. . .	89·05	31·50	91·9	89·0	88·70	. . .	. . .
12	4 54·2	. . .	69 05	20·60	72·3	69·2	69·08	. . .	. . .
	4 56·2	. . .	69·05	20·63	72·3	69·2	69·13	+ 0·03	+ 0·1
13	4 57·2	. . .	69·05	20·60	72·3	69·1	69·08	. . .	. . .
	4 59·0	. . .	69·05	20·62	72·3	69 1	69·12	. . .	. . .

Taking the means of each set, and applying the corrections indicated in the last two columns, we have the following table, showing the corrected standard readings in Fahrenheit degrees as compared with the readings of the metallic thermometers, Nos. 23 and 22:

Number of the Pair.	Mean of the Times.	Mean of the W. O. Thermometer in Fahr.	Mean of Y. O. 53 in Fahr.	Corrected Mean W. O. Thermometer.	Corrected Mean Y. O. 53.	Mean of the Mercurial Standards.	Mean of No. 23.	Mean of No. 22.
	h. m.	degrees.	degrees.	degrees.	degrees.	degrees	degrees.	degrees.
1.	12 49·4	27 00	27·45	27 00	27·39	27·20	27 80	27·05
2.	12 55·2	27 10	27·32	27·10	27·26	27·18	27·90	27·10
3.	1 0·5	27·25	[27·50]	27·25	27·44	27·35	28·15	27·30
4.	1 5·0	27·45	27 68	27·45	27·62	27·54	28·20	27·60
5.	1 12·3	27·57	27·91	27·57	27·85	27·71	28·30	27·60
6.	1 37 8	38 31	38·43	38·43	38 51	38·47	39·20	38·70
7.	2 7·6	68·75	68·72	68 85	68·75	68·80	70·55	68 90
8.	2 18·3	68·57	68·57	68 67	68·60	68 63	70·30	68·70
9.	4 13·3	89·25	88 92	89·25	89·05	89·15	91·90	89·00
10.	4 16·8	89 07	88·83	89·07	88 95	89·01	91·90	89·00
11.	4 19·7	89·03	88·72	89·03	88·85	88·94	91·90	89·00
12.	4 55·2	69·05	69·10	69·15	69·13	69·14	72·30	69·20
13.	4 58·1	69·05	69·10	69·15	69·13	69·14	72·30	69·10

From the above we readily deduce the corrections to be applied to Nos. 23 and 22 to reduce their face readings to the true temperature of the comparator as follows:

Number of Observations.	Point of Ther. Scale F.	Correction to No. 23.	Correction. to No. 22.
	degrees.	degrees.	degrees.
5	27·4	— 0·65	+ 0·09
1	38·5	— 0 73	— 0·23
2	68·7	— 1·71	— 0·08
3	89·0	— 2·87	+ 0·03
2	69·1	— 3·16	+ 0 04

Analyzing the above results, we see that No. 23 fails to return to its agreement with the mercurial thermometers at 70°, after it had been compared at 90°, by 1·4°.

No. 22, however, shows a remarkable agreement with the scale of the mercurial thermometers both ascending and descending. With the exception of its deviation at 40°, which is still less than ¼° F., there seems to be no deviation of its scale as great as ·1° F.

This, for commercial purposes, is a practical agreement with the perfect mercurial thermometer at ordinary temperatures.

It is not improbable that the coincidence extends in practical agreement with the Fahrenheit scale to some degree above the point of boiling water. On this point, however, your committee has had no opportunity to satisfy itself.

The instruments impressed your committee with their neatness of design and legibility of dial. They seemed peculiarly appropriate for ordinary air temperature use, and have the merit of revealing the temperature at a glance from any point of an ordinary sized room. Your committee was informed that display thermometers of large size were prepared by the same company which were legible at half a block's distance.

Respectfully submitted,

LEONARD WALDO,

Sub-Committee of Section XXII.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXIII.

(SECTION IV-A, CLASS VIII, OF THE CATALOGUE.)

Electro-Medical Apparatus,

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MAY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

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1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXIII.—ELECTRO-THERAPEUTIC APPARATUS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of Section XXIII, upon "Electro-Therapeutic Apparatus."

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, September, 1885.

PROF. M. B. SNYDER,

Chairman Board of Examiners, International Electrical Exhibition:

DEAR SIR:—I have the honor to transmit the report on "Electro-Therapeutic Apparatus," as embraced under Section XXIII.

I remain yours respectfully,

HARRISON ALLEN,

Chairman Section XXIII.

PHILADELPHIA, September 16, 1885.

REPORT.

The committee has the honor to report:

That the first exhibit examined, was that of Mr. Otto Flemming, 1009 Arch Street, Philadelphia.

In this exhibit are shown an elaborate sixty cell cabinet battery; a wall cabinet for attachment to a stationary gravity battery; a thirty cell combined galvanic and faradic portable battery; a twenty cell galvanic battery; four sizes of faradic batteries; pedal rheotome; unpolarizable electrodes, etc.

EXHIBIT A.

FLEMMING'S CABINET BATTERY (SIXTY CELL.)

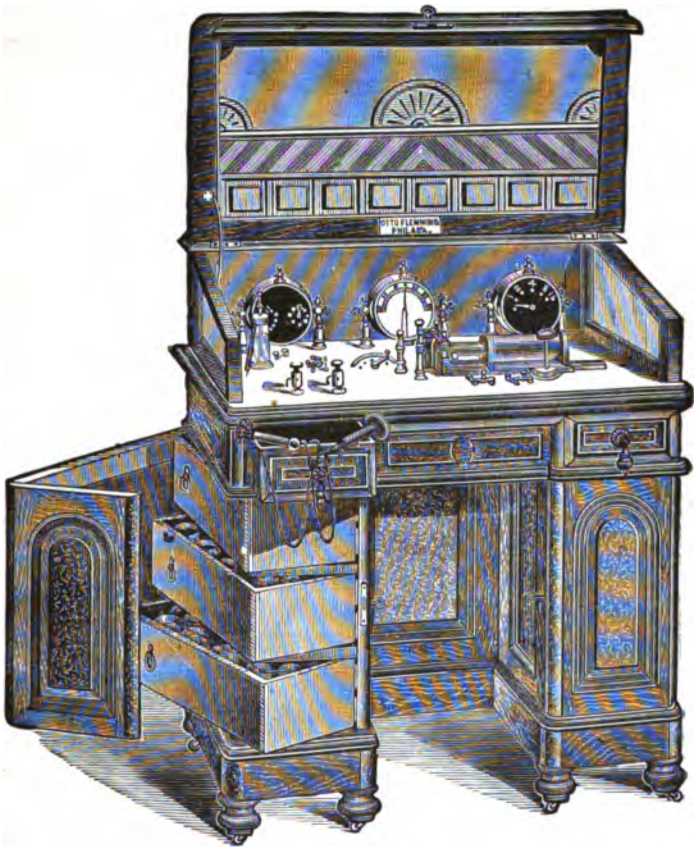
The cells of the battery are described by the manufacturer as follows: The elements are composed of zinc and carbon, the latter mixed with peroxide of manganese, granulated and placed in a glass jar to fill one-third of its capacity. In the centre of the jar is placed a glass tube, also filled with the carbon-manganese mixture, and a carbon rod with platinum wire connection (anode) so that the mixture in the centre glass tube is in unbroken contact with the mixture in the outer glass jar. A diaphragm is formed by tightly packing paper pulp on top of the carbon-manganese mixture, which is covered with a saturated solution of ammonium chloride and a zinc ring for cathode.

The objections to the modified Leclanché cell used by Mr. Flemming, are that it exposes too much surface for evaporation and is unnecessarily complicated in structure. The committee does not believe that the modifications are improvements, but the cell was referred for examination to Committee 14, from whose report the following figures are extracted: Cell No. 1, electro-motive force, 1·45 volts; internal resistance, 11· ohms; current strength in ampères at intervals of minutes at the start, ·12; after two minutes ·09. Cell No. 2, electro-motive force, 1·39 volts; internal resistance, 11.

The key-board of the cabinet battery contains an automatic mechanical rheotome, for interrupting the galvanic current, one, two, four, eight, or sixteen times a second; a galvanoscope, a wire rheostat, formed of a series of Siemens' resistance coils, a Du Bois-Reymond coil, with rapid and slow interruptions to the faradic current; the outer secondary helix being moved by a governing

screw, thus easily adjusting the currents. There is also a watre rheostat, furnishing resistance to the faradic current, and a commutator, changing the polarity of either the galvanic or the faradic current. A Grenet cell furnishes power for the faradic apparatus.*

The key-board of the faradic coil is well deserving of unqualified commendation. The special points to be commended are the



Sixty-Cell Cabinet Battery. (Flemming.)

appliances chosen for slow and rapid interruption of the faradic current, which are superior to any others examined by the committee, in that they give a much greater range in the rapidity of

* The descriptions of apparatus furnished by the committee, are usually modifications, or condensations, of those given by the manufacturers themselves.

movement, and are more rapidly and easily adjusted. The slowest rate obtained was forty per minute, whilst in rapidity, the slow rheotome could be made to approximate that of the rapid spring rheotome. The regulating screw of the faradic coil is a decided convenience, and the commutator is to be commended as durable and not likely to give trouble by getting out of order, but is considered inferior to the modification of the pole changer (in which the tires on the discs extend on one-quarter of a circle) used by Mr. Flemming on his portable galvanic battery, inasmuch as the latter admits of a more perfect break in the circuit.

The galvanoscope, which is useful to show that the circuit is made, does not afford any accurate measure of the power of such current, and in the complete galvanic table, it should be replaced by a dead-beat galvanometer, calibrated in milli-ampères.

There are two rheostats on the key-board, either of which ought to be so arranged as to be sufficient. The objection to the wire rheostat is its expense.

The fluid of the water rheostat should be a solution having greater conductivity than water; because water is so bad a conductor, that in the practical use of the simple water rheostat, it is almost impossible to avoid shocks when the metal conductors are brought into contact. The same rheostat should be used for both currents.

The clock-work rheotome or current interrupter of the galvanic current is condemned as making too prolonged contacts, as being very liable to work irregularly and as offering but a limited range of rate of interruption. It is recommended that the excellent faradic interrupter to be found in the wall cabinet of Mr. Flemming be adopted here also.

EXHIBIT B.

FLEMMING'S WALL CABINET.

In a handsome walnut case, 40 inches high 25 inches wide and projecting 7 inches from the wall is contained a galvanoscope, a commutator, a Du Bois-Reymond coil with rapid and slow interrupter and a contrivance by which the slow rheotome of the Du Bois-Reymond coil can be used to interrupt the galvanic current. There is also a rheostat for both currents and appropriate switches. The key-board of this wall cabinet seems superior to that of Exhibit A,

in that the water rheostat is adapted to both currents and the rheotome automatic. A very valuable feature in this rheotome is that it gives brief periods of current passage with long interrup-

Wall Cabinet. (Flemming.)

tions. The water rheostat should undergo the modifications spoken of under Exhibit A. On account of the small space which it occupies and the ease with which it is kept neat, we believe that this wall cabinet is superior to the ordinary table form of key-board.

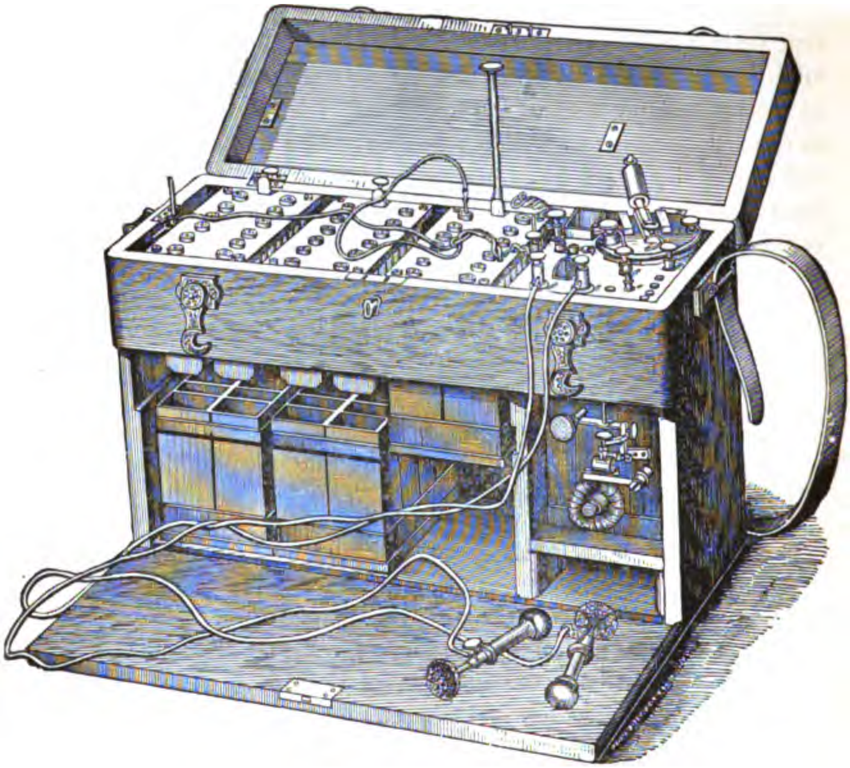
EXHIBIT C AND D.

FLEMMING'S THIRTY-CELL COMBINED BATTERY. FLEMMING'S TWENTY-CELL CONSTANT CURRENT GALVANIC BATTERY.

Both of these batteries are founded on the well-known Stohrer battery, much modified in its mechanical arrangements. It does not seem necessary to give a detailed description of them. Suffice it to say that each is supplied with a hydrostat, which is a rubber-cushioned sliding board, that is kept pressed down on the cells, when the battery is closed and serves to prevent spilling.

In Exhibit C, there is conjoined with the battery a faradic apparatus, provided with both rapid and slow interrupters, which is substantially the No. 3 faradic battery of the same exhibitor.

These batteries in their general mechanical arrangement, and remarkable excellency of workmanship seem to the committee to



Thirty-Cell Combined Battery. (Flemming,)

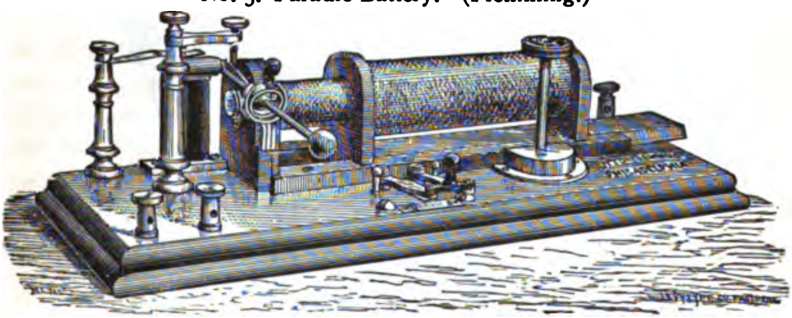
be the best forms of the portable bichromate batteries invented, but in practice they, like all other batteries of their character, are open to serious objections. Among these are the highly corrosive nature of the liquid employed, the closeness of the connections to this fluid, the great ease with which splashing occurs, allowing these connections to become corroded and the fact that the joints by any but the most careful handling are very apt to become loose and allow spilling.

EXHIBITS H, I, J AND K.

H.—Flemming's No. 1 faradic battery,
I.—Flemming's No. 1 faradic battery with slow interrupter.
J.—Flemming's No. 2 faradic battery,
K.—Flemming's No. 3 faradic battery.

These faradic batteries are furnished with the Grenet cell so made that when not in action, the zinc is raised out altogether and the aperture through which it passes securely covered with a rubber hydrostat, making the cell perfectly fluid tight and saving the zinc in transportation or in case of an upset. By this arrangement, the cell can be filled and the zinc immersed for its whole length. This form of cell the committee believe to be well adapted to the needs of the practitioner and commend it highly.

No. 3. Faradic Battery. (Flemming.)



Du Bois-Reymond Induction Coil.

The coils of these batteries are two in number.

The two exhibits, H and J (batteries No. 1 and No. 2), are much inferior to Exhibits I and K (batteries No. 1 with slow interrupter and No. 3), in the complete absence of the slow interrupter and in the inferiority of the rapid interrupter. We do not

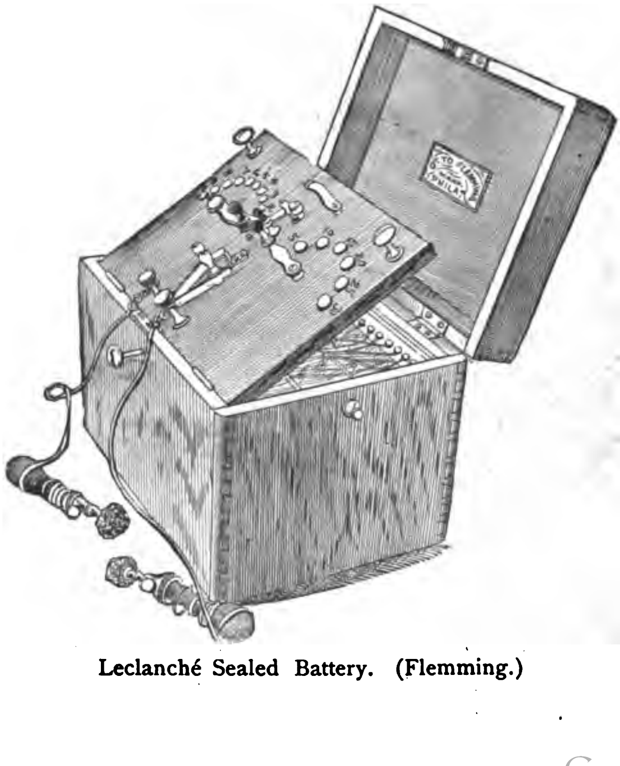
believe that either of these batteries is adapted for use in the physician's office.

Batteries I and K are furnished with interrupters similar to those on which we have commented in speaking of the cabinet battery. In the ease with which the current can be graduated, in the greater power derived from longer coils, in freedom from pretence, in excellency of workmanship, in convenience and general adaptability to the exigencies of daily practice, we know of no faradic battery equal to the battery K of Mr. Flemming; but for many practitioners, the lightness and cheapness of battery I, will give it preference, and the occasions must be rare in which it will not do all that is required of a faradic battery.

EXHIBIT M.

TWENTY-CELL PORTABLE SEALED CONTINUOUS CURRENT BATTERY.

This battery derives its current from a modification of the Leclanché element similar to that described in connection with the cabinet battery (Exhibit A), but in somewhat more compact form.



Leclanché Sealed Battery. (Flemming.)

The cells of this battery were referred to Committee 14, from whose report the following figures are extracted: Cell No. 1, E. M. F., 1·07 volts; internal resistance, 8 ohms; current strength at setting up, ·13 ampère, after one minute ·09, after three minutes ·07. Cell No. 2, E. M. F., 1·46 volts; internal resistance, 13·5 ohms.

The key-board of this battery is furnished with a galvanoscope, a commutator and an arrangement for current selection, similar to that of the cabinet battery of the same manufacturer.

In the absence of corrosive fluid and in permanency and constancy, this battery is much superior to any sulpho-chromate battery. To make it satisfactorily portable would require only that the mechanical arrangement be so altered as to close the cells more perfectly. To adapt it to the full range of medical uses, would require a distinct increase in the number of its elements. In its present form the battery weighs fifteen pounds.

In order to determine the exact value of this battery, the elements were referred to Section XIV.

EXHIBIT N.

MORRIS-LEWIS PEDAL RHEOTOME AND COMMUTATOR.

This instrument is designed to enable the electro-therapeutist

Pedal Rheotome and Commutator. (Flemming.)

to break the current regularly without the aid of the automatic rheotome or a spare hand. We believe that it satisfactorily accomplishes its object.

EXHIBIT O.

UNPOLARIZABLE OR HOMOGENEOUS ELECTRODES.

These are the well known unpolarizable electrodes of Du Bois-Reymond. They are well made, but seem to be better adapted to physiological research than the needs of practical medicine.

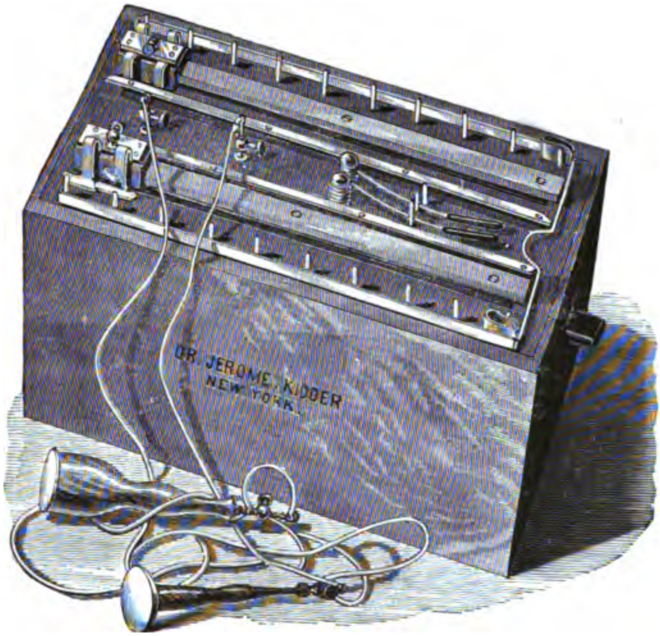
MRS. FRENCH'S BATTERY.

Mr. Flemming also exhibits certain batteries made in accordance with the general plan of his batteries, with the exception that the coils are more numerous, and are composed of various metals. By the varieties of the coils as to length, thickness of wire, and metals employed, it is claimed by the inventor (Mrs. French) that the batteries give rise to forms of current of essentially different physiological powers. The committee can see no reason to believe in the existence of such differences.

Mrs. French's Battery. (Flemming.)

THE KIDDER MANUFACTURING COMPANY, OF NEW YORK—GALVANIC APPARATUS.

The galvanic apparatus of these exhibitors consists of a sulpho-chromate battery (Battery A), and a large key-board for use with any desired form of cell.



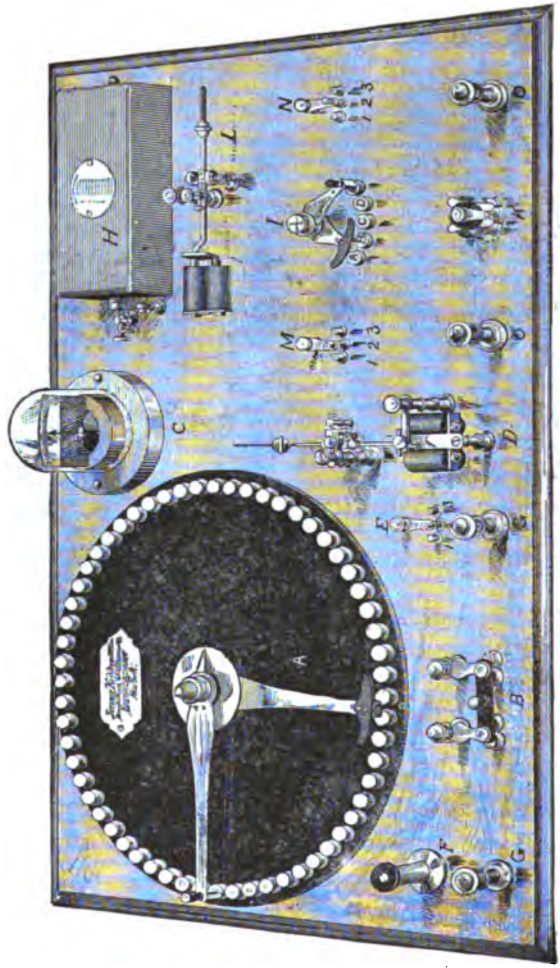
Battery A. (Kidder.)

Battery A is, in its elements and general form of construction, based on the well-known Stohrer battery. The objections to this form of battery have already been stated by the committee. (See Flemming's exhibit.)

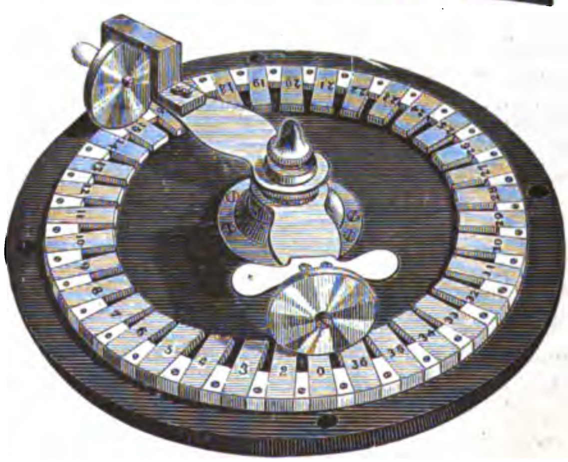
There are certain arrangements of the present battery worthy of commendation. Especially is this so of the selector slide. This is so arranged that by hooking back a spring the cells can be added, so as to make a series of shocks when the current is rapidly increased; and, by loosening the spring, the current can be increased without shock.

This battery is excessively heavy, and as its glass cells are fragile and cannot be closed, it is not at all portable.

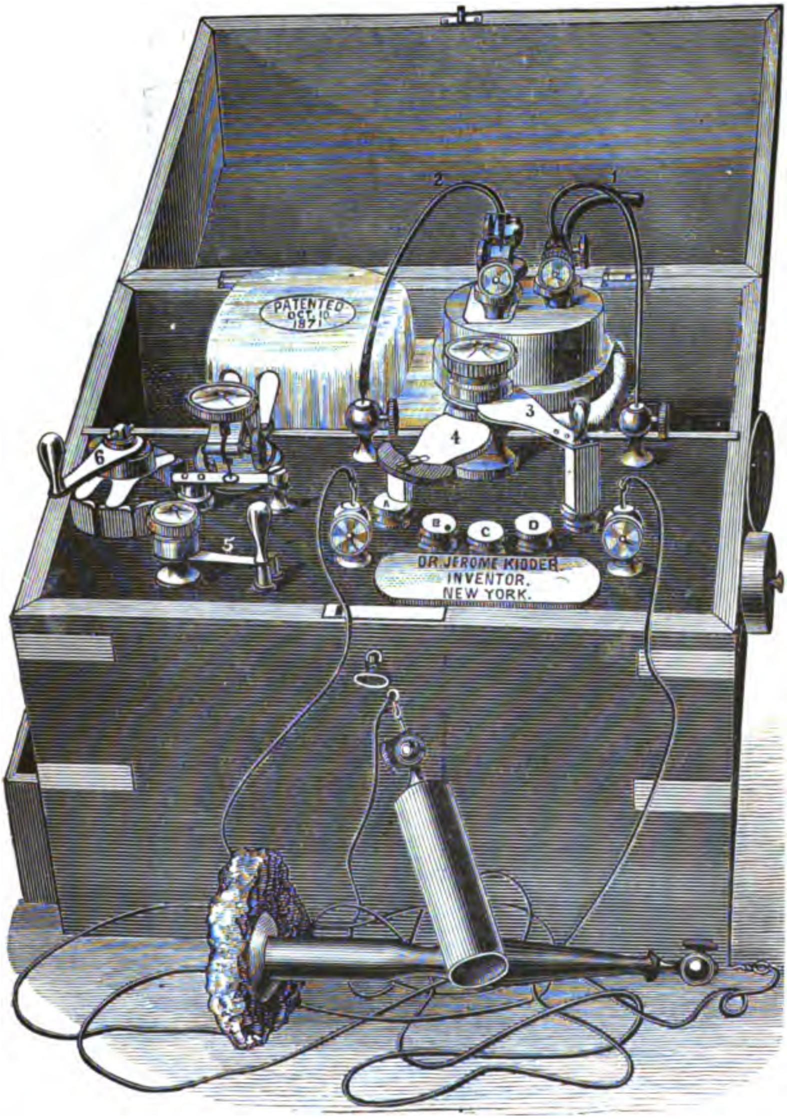
The key-board is adapted either to be placed on the wall or on a table. It is provided with separate commutators and separate terminal posts for the two currents, which duplication is not only unnecessary, but apt to give rise to annoyance. It is furnished with a galvanoscope and an automatic rheotome to interrupt the faradic current. This rheotome is not recommended because the



Stationary Key-board for any desired form of Cell. (Kidder.)



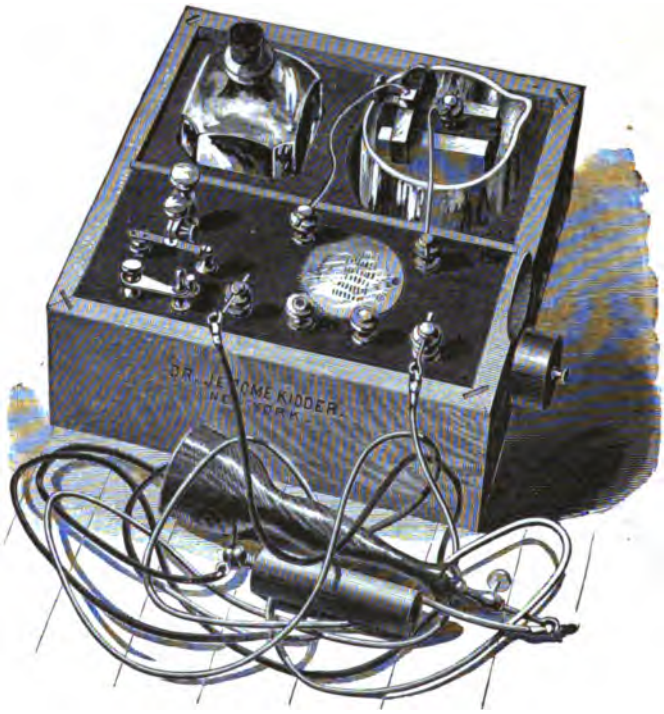
Current Selector for Stationary Battery. (Kidder.)



Large Faradic Apparatus. (Kidder.)

periods of current passage are very long while the interruptions are very brief. The commutator has the serious drawback that it cannot be used as a hand rheotome.

The arrangement for selecting the galvanic cells has the decided advantage of permitting a broken element to be thrown out of the circuit.



Faradic Battery with open Cell. (Kidder.)

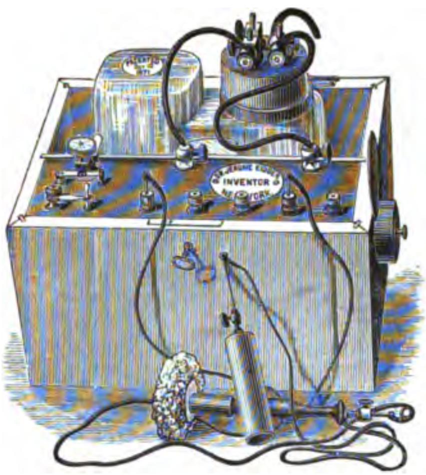
Open Smee Cell. (Kidder.)

There is no galvanometer.

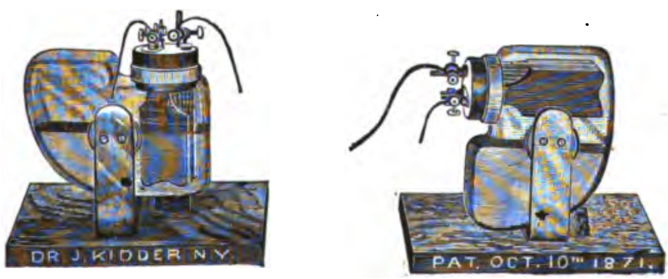
The key-board also contains a faradic apparatus similar to that used in Battery No. 2.

•The rheotomes, which are two in number, are of good character, the slowest vibration attained by the exhibitor before the committee was sixty per minute.

Six forms of faradic battery were shown by these makers, varying only in size and strength. They are so entirely wanting



Faradic Battery with Tip Cell. (Kidder.)



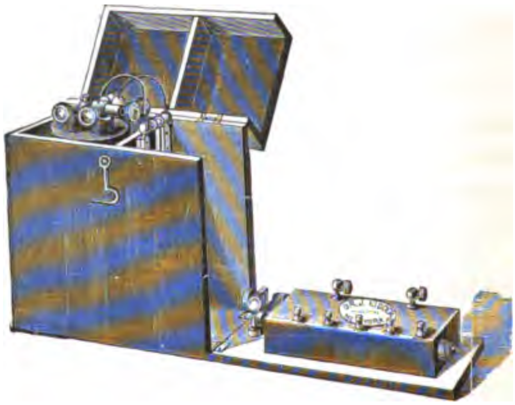
Hydrostatic Tip Cell. (Kidder.)

in any form of slow interrupter that in the opinion of the committee they are not adapted to the practical work of the physician.

The cell employed is a modified Smee element. In all, except No. 1 and No. 5, the cells are left entirely open and require emptying of their contents before carriage, or else they are only partially closed. Such an arrangement of elements is intolerable.

Batteries No. 1 and No. 5 are provided with so-called hydrostatic tip cells which, though large and cumbrous, are sufficiently tight; and when not in use, the elements are exposed only to the vapors and splashings of the acid.

The Smee element is employed in all these batteries. Whilst this is more permanent than the sulpho-chromate cell, the greater electro-motive force of the latter, we believe, recommends it especially for use in portable faradic batteries.



Physician's Visiting Apparatus. (Kidder.)

Smee Cell. (Kidder.)

The general induction coils, used by the Kidder Company, are composed of three or more coils of wire, each differing in length and diameter, which are joined in the binding posts in such a way that they can be used separately or in unison. It is claimed that from the large No. 1 battery with four coils, ten galvanic currents of different physiological power can be obtained.

The following, in their own words, is a description of the points of superiority claimed for their coils by the Kidder Manufacturing Company:

"We have first the primary coil, over which the influence from the battery travels, operating the automatic circuit-breaker

(rheotome), and producing a current of great quantity. Wound over the primary and thoroughly insulated is a coil having a greater length and smaller diameter than the primary coil and producing a current of greater intensity and less quantity than the current from the first coil.

"Over the first coil is wound a third coil, having a still greater length than the first and a small diameter, producing a current of still greater intensity than the second coil and of less quantity.

"In the ten-current apparatus we find a fourth coil over the third and the diameter of the wire is very small, while the length is greater than the total of the other three coils combined, producing a current of great intensity and adapted in quality for the relief of pain, etc.

"While the helix or coil is composed of various coils, they can be united so as to form one continuous coil, producing a great variety of qualities for the cure of diseases. The coils are so arranged, according to length and diameters of the wire, as to produce the best results with the battery-power that operates them.

"The influence of the primary coil or the quantity current from the battery can be conducted through the various coils of fine wire, or cut out of the circuit, so as to get the absolute induced currents from the induced coils when desired."

The general coil, in short, is composed of a series of coils, one within the other, all so arranged that they are or can be metallically connected from what is called a "continuous coil" machine. The innermost coil is short and made of thick wire; the next is longer and finer; the third is still longer and finer, and so on to the end of the series.

The number of coils used in the construction of the main coil varies with the size and price of the particular machine; thus one form of apparatus has two coils, another three and another four.

It is claimed that the different parts of this compound, continuous coil, can be so arranged and combined and so tapped, or drawn off for use as to give a large number of different currents or different variations of the qualities of the currents. It is claimed also that these different currents or different qualities of currents, produce different physiological effects, and different effects in the cure of diseases.

Great confusion and misapprehension may arise from the exhibitor's method of speaking of the currents in their various publications, as furnished to the committee. The first current derived from the primary coil is spoken of as "the primary influence," or "primary current," or "galvanic current." The next, "the first induced," etc. The facts being that the current from the first coil (A B), is simply the extra current or primary induced current and the others secondary currents.

It is well known that no galvanic current efficient for any medical purpose can be derived from the single cell of a faradic battery, and that the induced currents derived from coils superimposed upon one another, vary only in tension. All that can be said of this arrangement, is that certain induced currents of varying tension are obtained by the sub-divisions of the coil used. These currents undoubtedly vary in tension, but we were not able to obtain any clear evidence that these currents varied in their practical therapeutic effects.

The coil is one which is well adapted for all the therapeutic purposes for which faradic batteries are commonly used. The current or currents derived from it can be admirably regulated by the arrangement of the binding posts and regulator. The coil has no special disadvantages. What the committee objects to are the excessive claims of these exhibitors.

MR. FLIESCHMAN'S EXHIBIT.

The committee examined one continuous battery of this maker. It was made upon the general principles of the Stohrer battery, and is open to all the objections urged against this form. The mechanism appeared to be good, and we especially commend the simple arrangement by which a defective cell can be thrown out of the circuit and the current be increased cell by cell without shock.

The so-called large double cell pendulum battery is the chief faradic exhibit of Mr. Fleischman. The following claims are made for it by the exhibitor. A very regular and grateful current; the use of the pendulum interrupter, which requires very little power to keep in regular motion, when at rest is nearest the magnetic pole, has no loose connections, and that the coils are so arranged that there is a galvanic current in the primary current circuit.

The committee here reiterates what it has already said, that no efficient galvanic current can be derived from a single cell.

This battery certainly furnishes currents of very great power, but it appears to the committee to be lacking in delicacy, as is required in some departments of electro-therapeutics.

The sulpho-chromate galvanic element used is closed simply by an india-rubber cork, which is not retained by any mechanism, and is in our opinion liable to displacement. This greatly endangers the battery from the escape of corrosive fluid during transportation.

The so-called pendulum interrupter or rheotome is considered very worthy of commendation. It has the great advantage of having no joints to get out of order, and vibrates very steadily. The slowest vibrations claimed by the exhibitor before the committee were 112 per minute.

EXHIBIT OF MR. A. PARTZ.

The medical exhibit of Mr. Partz consists of a portable medical voltaic battery, which is described by the exhibitor as follows: It consists of fifteen tightly closed elements, 1⅝ inches square and 4½ inches high, applicable either together or in sets of three, six, nine and twelve, and contained in a box 6 inches high, 6 inches wide and 11¾ inches long, the whole weighing fourteen pounds. The electrodes are rods of zinc and carbon, the latter having been subjected to a peculiar chemical treatment having the effect of retarding polarization. The excitant liquid consists of a compound solution of about fifteen parts of chloride of zinc, and twenty-five parts of bichromate of ammonium in 100 parts of water.

For this battery, the following claims are made: The initial electro-motive force, as determined by Mr. A. Gaiffe, for one element is 1·65 volts; and after partial polarization through shunting, Count du Moncel and M. Hospitalier found its force to be 1·45 volts. (*La Lumière Electrique*, t. III, p. 168.)

The battery contains no acid, is free from all "local action," and may be kept in daily use for over a year without anything being done to it, provided that it be not unnecessarily exhausted by "short-circuiting;" that is to say, by placing the poles in contact without a part of the human body being inserted in the circuit.

In order to arrive at a positive conclusion concerning this

battery, it was referred to the Battery Committee, which reports as follows :

Cell No. 1, E. M. F., 1·22 volts; internal resistance, ·8 ohm; current strength at setting up, ·42 ampères; after two minutes, ·39; after four minutes, ·39; after six minutes, ·27; after eight minutes, ·24. Cell No. 2, E. M. F., 1·6 volts; internal resistance, ·45 ohms.

Various galvanic belts were examined by the committee, but none of them have sufficient galvanic power to exert any influence even upon the human skin and certainly not upon the organs beneath it, and we believe that they can only do good by acting upon the imagination of the patient.

H. C. WOOD, *Chairman*,
CHAS. K. MILLS,
JAS. HENDRIE LLOYD,
G. GRANVILLE FAUGHT,
LOUIS H. SPELLIER,
G. BETTON MASSEY, *Secretary*.

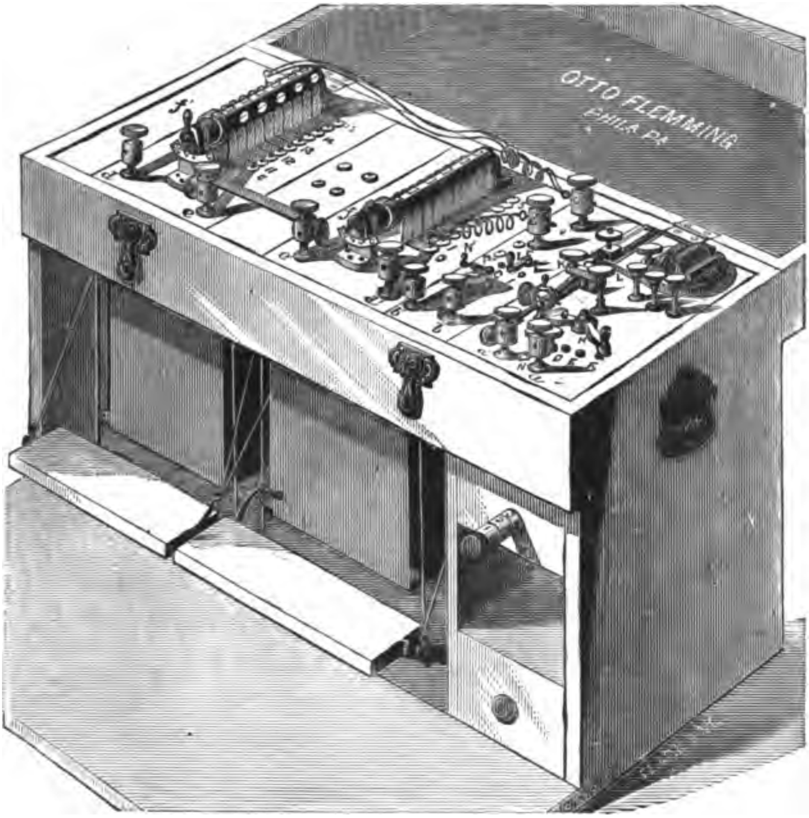
Members of the Sub-Committee on Therapeutic, Galvanic and Faradic Apparatus.

CAUTERY BATTERIES.

The single Cautery battery, upon which the sub-committee will report, is the Universal battery of Mr. Otto Flemming.

The novelty of the movement, as Mr. Flemming states, consists of two systems of ten-zinc and of ten-carbon plates, each of which is suspended from two hard rubber platforms. A brass spring is connected to each plate by a screw, which passes through the platform and presses against a cylindrical commutator. In the lower portion of the box are placed two hard rubber cups, which are partitioned off into ten compartments each. Each cup contains a mixture of bichromate of potassium, sulphuric acid and water. The cups are placed directly beneath the system of suspended plates, and are immersed in the fluid when the treadle is depressed.

The advantages of the battery are pronounced. It can be managed without the assistance of an attendant. It is easily kept



Universal Battery. (Flemming.)

in efficient order, and seldom disappoints the expectations of the operator. The contact of the liquid with the zinc and carbon plates (being dependent upon the movement of the foot) determines both the degree of activity of the elements and the length of time they have been brought in contact.

HARRISON ALLEN,
C. SEILER.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTION XXIV.

(SECTION IV, CLASS IX, OF THE CATALOGUE.)

ELECTRO-DENTAL APPARATUS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXIV.—ELECTRO-DENTAL APPARATUS.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXIV, on Electro-Dental Apparatus.

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXIV (on Electro-Dental Apparatus), respectfully present the following report.

J. FOSTER FLAGG, D.D.S., (*Ch'n. Section XXIV.*)

PHILADELPHIA, *December*, 1884.

ELECTRO-DENTAL APPARATUS.

This Section finds presented for its examination:

1st. The Bonwill Electro-Magnetic Mallet.

2d. The Dental Helix and Dental Electrode.

3d. The Electric Mouth Lamp.

4th. Numerous small Electric Motors, running either by dynamic or voltaic current, and adapted for dental use.

I. The Bonwill Electro-Magnetic Mallet.

[The Examiners here give a statement of facts and inferences bearing on the history of the application of electricity to the production of mechanical apparatus for treating the teeth, in which the services of Dr. Bonwill, as the originator of this type of apparatus, are set forth.—Ed. Com.]

The dental engine of Dr. Bonwill, run either by foot or motor is claimed to be the first devised, and it is claimed that, with the present improvements, it is an imitation of the human arm and wrist joint. It is capable of exceedingly high speed and the utmost delicacy of movement, and is of extended range, both as to power and application.

The surgical engine is the first ever devised and made *truly* practical.

It is a duplicate of the dental engine, with the addition of a multiplying attachment to give increased speed and power, and to enable the surgeon to be entirely free from any pedal movement, the assistant at the crank driving it with that great power which is needed in the heavy and prolonged operations on the human bones.

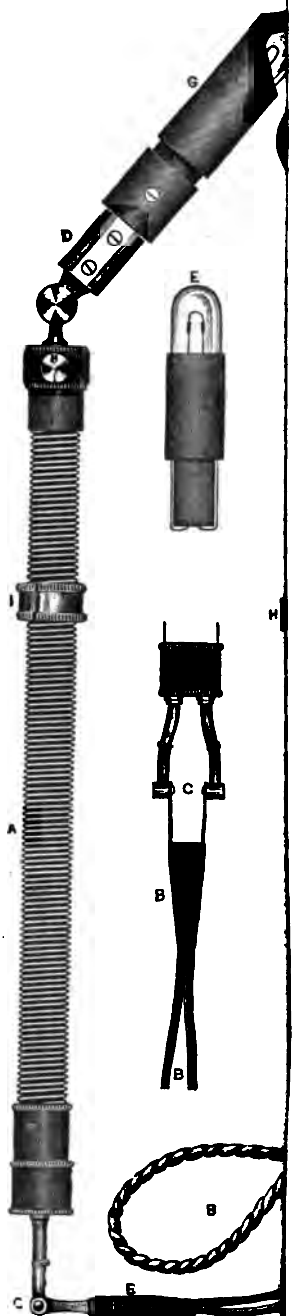
Its great velocity makes it more sure and steady in the surgeon's hand while performing, with elegance and delicacy, operations that no human hand could possibly be capable of.

The mechanical mallet is the outgrowth of Dr. Bonwill's mechanical pen.

Resumé.—The electric mallet was conceived Feb. 27, 1867. It was improved upon until 1876, and placed in its present practical shape in 1879. The first three forms had the stroke governed by clock-work rachet, which would run an hour. Since 1871–1872, the automatic brake has been upon the instrument, and has been made very compact.

The first electric mallet weighed one pound, and had to be suspended from the ceiling; the last one weighs but five and a half ounces, and is used in the hand with perfect facility.

The dental engine dates, at least, as far back as 1869.



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The surgical engine had its birth when the "human flexible arm" and the "universal chuck hand-piece" were devised, in 1876. The earlier forms of arm were not adapted for surgical work.

The mechanical mallet was brought out during 1876 and 1877.

Thus, through Dr. Bonwil, the dental profession is enabled to claim as among its gifts to suffering humanity these instruments, which do so much toward lessening labor, relieving pain.

II. The Dental Helix and Dental Electrode.

These instruments are made and exhibited by Mr. Otto Flemming, 1009 Arch street, Philadelphia, Pa.

The dental helix is a coil of wire, No. 20, Stub's gauge, fifty yards in length. This passes, in the usual manner, from a positive electrode, is coiled around a *covered* core of wires, and around a soft iron bar, to a rheotome stand-post. The current passes by this route through the rheotome to a screw-nib, and thence back to a negative electrode. The rheotome stand-post is utilized for a positive electrode, and two wires are attached to the main wire at a point upon the other side of the rheotome, and are led to a negative electrode.

By this shunting an induced current is obtained. Upon one of these two wires a switch is placed so that direct or open contact can be made; while into the circuit, upon the other, is introduced a water rheostat, by means of which, when the switch is open, such resistance is offered as permits the production of an interrupted current so delicate as to give, for its perceptible minimum, merely a slight taste (without sensation of interruption) when applied to the tip of the thoroughly moistened tongue.

This current can be gradually increased in strength until it becomes almost unendurably powerful.

From these possibilities this helix is especially adapted for operations upon the teeth, as the exquisite sensitiveness of the fifth pair of nerves (sensory to the teeth) is such as to render ordinary helix currents anything but agreeable.

This helix has, according to testimony presented from various persons, been very successfully used for the alleviation of pain, both in extraction of teeth and in the preparation of cavities of decay containing exquisitely sensitive tooth-bone.

The Dental Electrode.

This essential adjunct to the Dental Helix is a duplex electrode so arranged, shaped and connected that by the use of one hand it can be held and applied by the patient, thus securing a passage of current from the part to be operated upon to the hand of the patient, while the other hand of the patient is left free for the graduating of a precisely acceptable current, by means of the withdrawal or insertion of the core cover referred to above.

III. The Electric Mouth Lamp.

This appliance, in the exhibit of the S. S. White Dental Manufacturing Co., possesses for the dentist, so peculiar a value as to render it worthy of extended mention and minute description; not that its employment in this country of bright, clear daylight is frequently necessary, but that in almost all doubtful cases relating to pulp trouble and peridental irritation it gives a solution of such positiveness as to be simply invaluable.

The idea of illuminating the oral cavity is not claimed as original with this exhibit, but the various devices possessed only by the S. S. White lamp render it so eminently practical as to reflect great credit upon their Electrician, Mr. E. T. Starr. Of these we may speak; especially of the encasing of the lamp in a hard rubber non-conducting cylinder, with mirror attachment, so arranged that, by rotation of the casing, it completes the universal joint motion partially attained by the hinge which connects the lamp to the handle; and also of the "resistance handle;" which not only affords greatly increased safety against injuring the carbon loop of the lamp, but at the same time, so regulates the flow of current that any desired degree of illumination may be easily and promptly obtained.

The effects resulting from the use of this lamp as an oral illuminator are peculiar and beautiful in the extreme; the teeth and gums are, if in a normal condition, singularly translucent, and the slightest deviations from the normal condition are wonderfully conspicuous.

Those who have used the lamp for the ordinary work of additional illumination during the preparation of cavities, and the introduction of filling material during dark days, report it as of marked assistance, and not so detrimental to sight as would be the effort of straining the unaided vision.

In use, the lamp is placed behind the object to be illuminated—that

is, so that the object is interposed between the lamp and the eye of the observer. Thus, in examining the teeth the lamp is placed within the arch, so that its light falls upon the lingual or palatal surfaces of the teeth, while the eye of the operator is directed to the labial or buccal surfaces.

Description of the Cut.—The lamp *E* is an incandescent electric light mounted permanently in a non-conducting case or cylinder of hard rubber. The lamp is supplied with metal conductors which pass outside of the section of the case. The lamp case is carried in another hard-rubber cylinder, *D*, called the lamp-holder, which is also supplied with metal conductors fitting those on the lamp case, the two parts when adjusted being clamped together by the set-screw *F*, thus holding the lamp firmly in its socket. The conductors of the lamp-holder are connected to the handle, *A*, by hinged joints, so that almost any desired adjustment is readily secured. This handle is called a resistance handle because it is wrapped with wire of a low conducting power, by which, through the agency of the ring, *I*, the flow of the current is regulated. When the ring is placed at the end of the handle nearest to the battery-cord the resistance is reduced to the minimum and the current from the battery flows freely to the lamp. Sliding the ring to the opposite end of the handle compels the current to travel through the wire with which the handle is wrapped to the ring and back again, thus forming a resistance. The connection to the battery-cord, *B*, is made by the spring-coupling, *C*. A non-conductiing guard or shield, *G*, is placed over the lamp-globe for the double purpose of preventing the radiation of heat, and of directing the light to any point desired. At *H* is a screw for breaking the circuit. The circuit should be broken occasionally during a prolonged examination, and also whenever the lamp is not in use, to prevent its becoming so hot as to be unbearable in the mouth.

For the examination of posterior cavities in the teeth a mirror set at an angle of 45 degrees is attached to the end of the guard.

Battery Power—It has been found impossible so far to make the lamps of exactly equal power, but the variation is not great. To develop their full capacity requires about 3½ to 5 volts—say the current from three cells of a Bunsen battery. The cells of the battery supplied with the Electro-magnetic Mallet are excellent for the purpose, or three cells of any bichromate battery will answer.

Caution.—When connecting the lamp to the battery-cells always

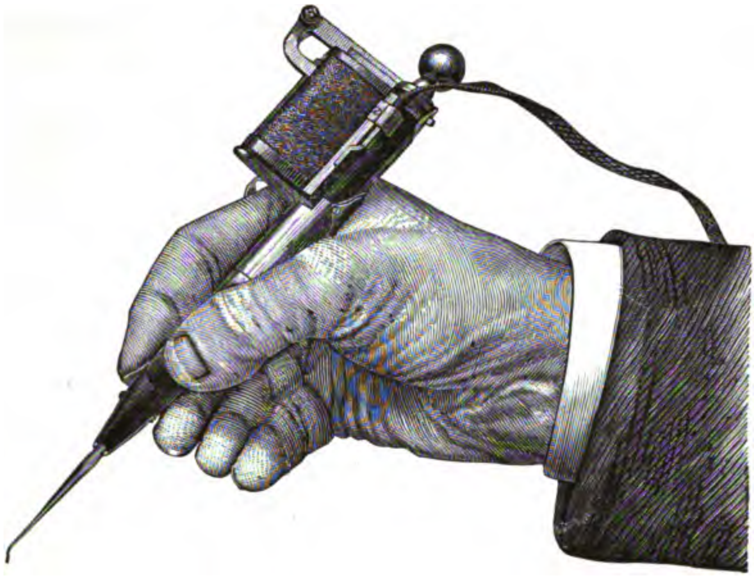
have the ring *I* (see cut) at the lamp end of the handle. If on turning on the current it is found insufficient to develop the full illuminating power of the lamp, slide the ring down the handle until the proper current is found. If through neglect of these precautions too much current be turned on it will probably destroy the carbon loop of the lamp.

In the S. S. White Dental Manufacturing Co.'s exhibit is also found a sample of the present perfected Bonwill electro-magnetic mallet, regarding which we publish a reprint of portions of their pamphlet upon this instrument.

How the Mallet is Operated.—Connect the instrument with the battery by passing the tubes attached to the silk mallet-cord *A*, over the two pins (on its reverse side, but not seen in the cut). Place the index finger through the ring *B*, resting upon the slide *C*; a very gentle pressure of the end of the finger upon the flange of the slide closes the circuit. The armature *D*, being thus attracted to the electro-magnets *E*, strikes upon the hard-rubber piston or plunger *F* (this is adjusted by the screw-nut *G*), against which rests the swell-end of the packing instrument *H*. Every time the armature is attracted to the magnets, it strikes the plunger *F*, and, at the same time, the rod of the interrupter *I*, thus breaking the circuit at *K*. The armature is then forced away from the magnets by the spring *L*, and is caught at *M*; the rod of the interrupter is carried back to its position by the recoil-spring *N*, which surrounds it, and the circuit is again closed,the instrument being thus kept in operation as long as pressure is continued upon the flange of the slide. The length of stroke of the armature or mallet is regulated, and the force of the blow to a certain extent controlled by the nut *O*, acting upon and firmly setting the rod *P*. The sound is lessened by the hard-rubber *M*, in the top of the slot. The packing or filling instrument *H*, which passes through the hand-piece, is controlled by the thumb through the opening *R*. The springs *Q* (one on each side of the hand-piece) keep the instrument in contact with the plunger *F*.

As each piece of properly-prepared foil is passed over the flame o alcohol and introduced into the cavity (either by an assistant with light-pointed foil-carriers, or by the operator), and simply attached to that already there, the instrument, *H*, being in position, the mallet should be set in operation by a slight pressure of the index finger upon the

flange of the slide *C*. The instrument *H* should be held in place and guided very nearly in the same way as a pen or pencil.



One position of the hand in holding the electro-magnetic mallet is here illustrated, the thumb and index finger serving to steady and guide the instrument in the same way as a pen or pencil, and to close and open the circuit.

Some of its principle advantages are :

First.—The blow is delivered upon the packing instrument just at the point where its force is greatest.

Second.—The force of the blow upon the gold can at all times be controlled by the operator.

Third.—Properly used it condenses the gold thoroughly and evenly throughout the entire filling.

Fourth.—Gold may be placed against thin, frail walls, and made compact without fracturing the enamel.

Fifth.—It saves the operator time and the fatigue attendant upon the use of a hand, automatic, or foot-power mallet.

Sixth.—When its operation is understood and the battery is kept in order according to instructions, the instrument does not require any more attention than a watch.

IV. Electric Motors adapted for Dental Use, running by either Dynamo or Voltaic Current.

A number of small motors (though for various reasons, not all that were upon exhibition) were presented for examination by this section. Among those tested, but three are deemed worthy of notice as specially adapted to the requirements of the dentist. These are the Edgerton, the Van De Poele and the Griscom or "Double Induction." Of these three motors as in comparison with all the others, we can say that they are very greatly superior. In comparing these three motors with each other the accomplishment of our desire to do full justice is more difficult, inasmuch as a $15 instrument is placed in competition with a $25, and a $30 instrument. We can, therefore, only give results, and with the few necessary comments for and against each motor, leave the decision as to positive superiority to be governed by the requirements of each individual demand.

1st. *The Edgerton Motor*, weighing twenty-two pounds, and costing $30, gave decidedly the most work under an electro-motive force of 5 volts. If, therefore, the weight of the motor was not objectionable, and the price was not too great, there would be found with it the decided advantage of capability with the expense and care of but three, or at most, four cells of battery. It was also found that with 8½ volts (five cells) an amount of power was given which far exceeded the limits of dental requirements. For these reasons the Edgerton motor was ranked as *first*.

The Edgerton Motor.

2d. *The Van De Poele Motor*, weighing nine pounds ten ounces, and costing $25 gave a very satisfactory response under a current of 5 volts. It is a very well made and beautifully balanced instrument, and it also

developed an amount of power under $8\frac{1}{2}$ volts, quite sufficient for dental purposes.

3d. *The "Double Induction" Motor.*—This is a small, compact motor weighing but two pounds, six ounces, and, therefore, capable of easy suspension in close proximity to the dental chair. Its cost is but $15, but it requires a high electro-motive force and cannot be run to any advantage with less than from 10 to 12 volts, necessitating a battery of at least six, and preferably seven cells. It should, however, be stated that with a *sufficiency* of power (15 to 20 volts) the capabilities of this little motor are something surprising, and it therefore becomes specially adapted for the direct attachment of circular saws and burs, as illustrated in the engine for both light *and heavy* work in general, oral and dental surgery, as devised by Dr. M. J. Roberts, of New York. As utilized by this engine, the "Double Induction" motor, under a current of 20 volts, will fulfill any demands that can be made upon it. It must be distinctly understood, that the development of power on the part of the two preceding motors under increased volts, is proportionately great, and it was, therefore, deemed necessary that they should have precedence. All of which is respectfully submitted.

J. Foster Flagg, D.D.S., *Chairman.*

Cyrus Chambers, Jr.,
Walter M. James, M.D.,
James Hendrie Lloyd, M.D.,
Charles K. Mills, M.D.,
Samuel Sartain,
C. Seiler, M.D., *Secretary.*

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXVI.

(SECTION VII, OF THE CATALOGUE.)

"Applications of Electricity to Artistic Effects and Art Productions," with which is Incorporated Section XXV, "Applications of Electricity to Musical Apparatus."

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MAY, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXVI.—APPLICATIONS OF ELECTRICITY TO ARTISTIC EFFECTS AND ART PRODUCTIONS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXVI, on "Applications of Electricity to Artistic Effects and Art Productions."

Respectfully,

M. B. SNYDER,

Chairman Board of Examiners.

PHILADELPHIA, January, 1886.

PROF. M. B. SNYDER,

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXVI, respectfully present the following report.

FRED. GRAFF,

Chairman Section XXVI.

PHILADELPHIA, January, 1886.

REPORT:

THE APPLICATIONS OF ELECTRICITY TO ARTISTIC EFFECTS AND ART PRODUCTIONS.

The Committee at its several meetings very quickly came to the conclusion that, owing to exhaustive sub-division of the labors of the Board of Examiners, very little original sphere of action remained for its consideration. Two subjects, and only two, appeared to call for report under its functions. (1.) The influence of electric lighting upon decorative taste. (2.) The application of electric lighting to photography.

I.

Whoever visited the exhibition at night, needs no reminder of the growing applications of electricity to the production of artistic effects. By its aid, the crude building, hurriedly erected without attempt at finish for a temporary purpose, was transformed into a temple of light, which at the first glimpse evoked expressions of delight from every beholder.

The exhibits of Edison and Weston were especially worthy of remark in foreshadowing the future general use of electricity in domestic decoration. Revolving stands laden with flowers, whose beautiful bright columns were disclosed by the electric lamps distributed amid their green foliage; purling fountains subsequently illuminated with various hues; glowing bouquets, all apparently usual features of a modern drawing room, gave a foretaste of the æsthetic furnishing of the future. It is evident that the general introduction of the electric light must have a most decided effect in the modification of everything that appeals to our taste. House decorations, dress materials, must all be fabricated with the condition of producing maximum pleasing effect under powerful and searching electrical illumination. The vista of possibilities of discussion opened from this point of view is illimitable, and the section has concluded—wisely it is hoped—to refrain from entering it. A probable reflex result may, however, be mentioned.

Physicians agree that we suffer in our homes from want of sunlight. We furnish, dress, and live for gaslight. When our surrounding shall have been accommodated to the brilliant illuminant of the future, we need no longer shut out the bright light of day,

under whose health-giving sheen, dull eyes and waxen cheeks will brighten and bloom

II.

Mr. W. Curtis Taylor, of Philadelphia, established an electrically lighted *atelier* in the Exhibition Building, and thus gave opportunity to thousands of practically witnessing the photography by electric light.

Owing to the circumstances of the case, he was necessarily cramped in room, yet notwithstanding this drawback. he was very successful in results. His method is fully described in the report herewith appended. Mr. Kurtz, of New York, exhibited some remarkably beautiful photographs taken by electric light. The Chairman and Secretary of the Section visited his studio in New York, and through his courtesy and that of his assistant, Dr. Ehrmann, were placed in full possession of the details of his method of procedure.

The apparatus employed by Mr. Kurtz, as will be seen by the description and wood-cuts given in Appendix B, is much more elaborate than that used by Mr. Taylor, requiring a skilful and artistic operator to manipulate the numerous lights and the movable posing platform.

Mr. Taylor's whole arrangement is exceedingly simple, can readily be erected and put in use in the usual photographic gallery. Its manipulation is comparatively easy, the cost of getting up the apparatus is low, compared with that as employed by Mr. Kurtz. It must, however, be conceded that the latter gentlemen has produced with his arrangement wonderfully artistic and perfect work, quite as good as many made by daylight.

Mr. C. H. James, of Philadelphia, exhibited some striking views of parts of the "Caverns of Luray," taken by electric arc lights, in 1882. The details of the method of doing this difficult work are contained in Appendix C.

FRED. GRAFF, *Chairman.*
O. E. MICHAELIS, *Secretary Section XXVI.*

APPENDIX A.

1328 Chestnut Street, Philadelphia.

FRED'K GRAFF, ESQ., *Chairman, etc., Section XXVI, International Exhibition* FRANKLIN INSTITUTE.

DEAR SIR:—As an accompaniment to the collection of photographs, which I shall have the pleasure of presenting to the FRANKLIN INSTITUTE, I beg to offer the following description of our studio in the Exhibition Building, where the negatives were made.

Since making the experimental photographs, in the hall of the FRANKLIN INSTITUTE, in 1877 (believed to be the first made by electric light in America), I had not used artificial light for making negatives until my present arrangement was put into operation at your Exhibition.

Methods elsewhere adopted for photographing from life by electric light may be classed under two principal heads: (1.) The use of one or two powerful lights in conjunction with condensing reflectors of moderate size, and (2) the use of a large number of moderate lights without condensation.

In the first, it is sought to avoid the hard effects by making either the lamps or the sitter change position constantly during the operation, in order to round off the shades and produce modulation of the features. The former is the method of Liebert in Paris and Van der Weyde in London. I am able to lend for your inspection photographs by Liebert, taken at the Paris Exhibition, in 1881; and you have, in your own Exhibition, specimens of the work of Van der Weyde. I think you will agree that in each of these is a too definite line of demarcation between the lights and shades.

Mr. Kurtz, of New York, makes his sitter and camera box revolve together under a fixed light. He also has specimens in your Exhibition. Being a skilful and pains-taking artist, Mr Kurtz has produced excellent effects by this means, where the mere photographer would have made a miserable failure. As a strong objection, however, to his method, I submit that most sitters would find it very inconvenient to be swinging about; as at such a time they find it hard enough to keep tranquil even under the most favorable circumstances.

Mr. Mayall's light in London, is on the principle classed above as second. He uses a great number of Swan's incandescent lamps,

arranged in circles over and around the sitter, but so far as my latest information goes, no general diffusion or softening of the light is otherwise attempted. It cannot be agreeable to the eye. I have seen no specimens of his work.

It was my object, when preparing for the present Exhibition, to imitate as closely as possible the natural daylight effects of our permanent studios, the result of long and general experience of photographic needs. The problem, then, was to produce a flood of gentle, but sufficient, white light, to cover such an area at the top and one side as should throw over and around the subject, from this *one* source, a light of its own nature diffused and requiring no counter lights for its modification. This is precisely what we do in our skylights. To effect the same purpose at the Exhibition we placed two arc lights of 1,000 candles each near the central line of the studio, 4 feet apart, and about 8 feet 6 inches from the floor. The light nearly overhead to the sitter is covered with a porcelain globe; the other with a glass globe, ground on the lower

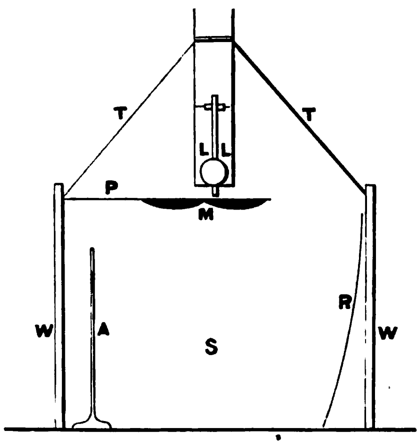


FIG. 1.—Section of Studio at International Exhibition of FRANKLIN INSTITUTE. Plan by W. Curtis Taylor. 1884.

W W.—Side walls of studio.
L L.—Arc lamps arranged parallel with sides of room.
T.—Tent.
P.—Tissue paper to diffuse light.
R.—White drapery, adjustable; for reflection.
A.—Dark screen, adjustable; for absorption of light.
S.—Usual position of head of sitter.
M.—White muslin, to subdue too intense light over sitter's head.

half and clear above. Covering these was a white muslin tent, the whole size of the apartment (which was 10 x 12 feet) and rising at the apex about 4 feet above the lamps. Spread on wires below the lamps was a sheet of silicated tissue paper, nearly the size of thetop of the room, and about eight feet above the floor. This served the double purpose of further diffusing the great body of light shed down from the lamps and the white tent, and of bringing the light nearer to the floor, thus increasing the angle of illumination. This paper stopped about 2 feet 6 inches short of that side of the room corresponding to the "side light" of an ordinary studio, in order to allow the unobstructed light to pass over it at that place. The free light from above here fell upon a white muslin reflector, hung on the wall, and reaching to the floor. The force of this reflector was varied by inclining it at a greater or less angle to the light rays. On the opposite side of the room a greater or less exposure of dark drapery determined the position and depth of shade required for artistic effect.

From what is here stated, it will be seen that the prominent and peculiar feature of this plan is the simplicity of its means for producing around the subject a great extent of diffused and non-brilliant light. The common remark of all who saw it for the first time was that it was "softer than daylight," yet it was sufficient to make a perfect dry plate negative in six to twelve seconds.

On this, the closing day of the Exhibition, I will add, as the result of our experience, that nothing was needed to make our experimental light right as to principle but more space in our studio. There is a certain atmospheric effect, hard to be described, which it is impossible to get in a little cooped room.

Respectfully submitted,

W. CURTIS TAYLOR,

October 11, 1884.

APPENDIX B.

Mr. Kurtz endeavors to secure as thorough diffusion of the light as possible by multiplying the number of arc lamps, and providing each with globes of ground oropaline glass, or with lanterns of thin tissue paper. The lights may also be grouped in various ways relatively to each other. But not satisfied with this, Mr. Kurtz resorts to the expedient of placing both the sitter and the

camera on a platform pivoted on a centre pin, and of rotating the platform during the operation of photographing so as to vary the angle at which the light from each lamp strikes the sitter. In this way the light is made to strike each feature at every angle as it passes successively from a shady to a lighted position or vice-versa, and thus an artificial diffusion is obtained which produces superior blending effects in the lights and shadows of the picture.

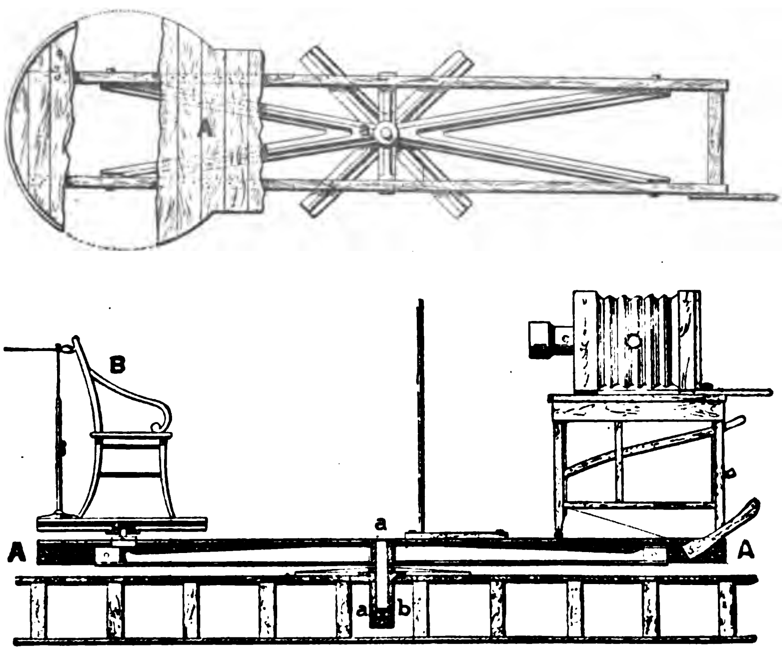


FIG. 2.—Plan and Section of Turn-table.

A.—Movable platform.
B.—Chair for sitter.
C.—Camera.
a b.—Pivot upon which the platform revolves.

The camera occupies one end and the sitter the other end of the platform, which is raised above the floor and turns on its centre on a steel pin which is received in a vertical bearing in the centre of the floor. The frame of the platform consists of two cross beams superposed at the centre, and supporting two parallel beams extending lengthwise and upon which the flooring is laid transversely.

This construction gives great solidity to the platform and diminishes the chances of vibration, whether lateral or longitudinal, by which the sitter and the camera might be disturbed relatively to each other, as the platform is rotated by the operator. This is important, for if the platform vibrated in this manner the image in the camera would be displaced to and fro to a slight extent, and the picture would be blurred and indistinct. A curved screen placed behind the sitter serves as a kind of concave reflector, which assists in diffusing the light from the lamps. The camera stand is supported on wheels, and it is movable on a small track (not shown in the engraving) from one side of the platform to the other in the arc of a circle of which the centre is exactly at the point occupied by the sitter. This innovation will greatly interest photographers, and it reflects credit on the ingenuity of Mr. Kurtz. The utility of this arrangement is very great. It is customary, at least in this country, to take several views of each sitter, in different presentations, such as full face, right side, left side, etc., and let the sitter select from the proofs of the negatives that which is the most suitable. In every case it is necessary to re-focus the camera with each change of position. But with this arrangement the camera remains in focus as it moves, and thus two or more positions may be photographed without trouble to the operator, who simply pushes the camera sidewise and exposes a fresh plate. The arrangement by which the operator is enabled to dispose the lamps at the convenient distance, and in the proper relation to the sitter, is most ingenious, and recalls the overhead railways found in machine shops where heavy pieces of machinery are to be moved from one machine to the other. The group is composed of six arc lights, which are suspended from a transverse frame extending horizontally from one side of the room to the other at a little distance below the ceiling, and which constitutes a travelling carriage, provided with wheels or rollers and moving on wooden rails extending from one end of the studio to the other on each side and supported by wooden brackets.

The transverse frame itself carries a smaller carriage which moves from one side of the room to the other, and supports the screen-holder, consisting of a horizontal frame which rotates on a vertical pin projecting down from the smaller carriage. To this frame, a flat screen is hung on couplings, so that it may be disposed

at any angle, from the vertical to the horizontal. The larger or main travelling carriage supports three of the six arc lamps, and the screen-holding frame supports the remaining three. It will be seen that in this way the lights are in reality divided into two groups which can be moved together or singly. Thus, when the transverse frame is moved, the whole system moves, but when the smaller carriage is moved, from side to side, only three lights are moved, thereby establishing a new relative position between the two groups, which may be varied still further by swinging the screen-holder which supports them. Not satisfied, however, with the facilities for varied diffusive effects which this arrangement affords. Mr. Kurtz has provided each lamp with its own small travelling carriage, so that the lights of each group may be moved from side to side as occasion requires.

Mr. Kurtz has adopted the electric lighting system of the Excelsior Electric Company of this city.

The time of exposure is not greatly in excess of that required under an ordinary skylight. A cabinet size head taken with a 3 B Dallmeyer lens, using a No. 2 stop and on a plate of average capacity (Mr. Kurtz's own manufacture in most cases) requires five to eight seconds, although the time has been reduced to three seconds under special circumstances. For measurement, a metronome is used.

In the basement of the premises connected with the main establishment, there is a branch for the photographing of technical and other inanimate objects; for the reproduction of maps, prints, drawings, etc.; silver printing and the making of process plates—all being done by the electric light. Here was recently accomplished the photographing of the electric spark of the telephone in the $\frac{1}{24,000}$ part of a second.

APPENDIX C.

The negatives, from parts of the Caverns of Luray, of which photographs were exhibited, were taken in the year 1882, by Mr. C. H. James, of Philadelphia.

The pictures intended for the stereo, on 5 x 8 plates, were made with a pair of Dallmeyer's quick-acting four and one-half focus single view lenses; those on 7 x 9 plates, with an eight-inch focus Ross portable symmetrical lens, and the large 18 x 22 plates,

with an eighteen-inch focus Ross portable symmetrical lens, almost all the pictures being taken with the smallest stop of the respective lenses. The exposures with the first named averaged two and one-half hours, the 7 x 9 three and one-half, and the 18 x 22 as much as eight hours.

The focussing was difficult, and accomplished by means of a lighted candle set upon such spots as it was desired to photograph.

The illumination by which the pictures were made, was supplied by the Thomson-Houston arc lights, with which all the most frequented parts of the cave are furnished. These are supplied from the dynamo in an engine house at the hotel, at a distance of nearly a mile from the cave, communication being kept up between the operator and the engineer by telephone.

The power of the light was estimated at 3,000 candles, and in all cases where the character of the subject required more than one of the lamps, the greatest care was taken in the management of the illumination, which was reënforced by the use of a screen or partial reflection of white paper immediately behind the lamp, so as to break up the light, modify and deprive it of its extreme harshness. Much of the success was attributed to the skilful use of this device. Indefatigable patience and hard work was required to obtain successful results.

Mr. James found the electric light exceedingly deceptive, for in many cases when but little or nothing could be seen upon the ground focussing glass of the camera, comparatively short exposures gave good negatives.

The pictures were all taken upon gelatine dry plates.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

Report of Examiners of Section XXV, on the "Application of Electricity to Musical Instruments."

(Issued as a Supplement to Section XXVI.)

REPORT.

There was only one exhibit in this class, viz., the Roosevelt electric organ. Electricity is made to perform all the work of the "action." The "trackers," "rollers," "stickers" are dispensed with in the key action, and the various levers, etc., in the stop action, thus securing extreme simplicity, and consequently little liability to get out of order, and making it possible to place the key-board at any distance from the organ, and even move it from place to place if desired. The current is supplied by a Leclanché battery, and is utilized as follows: A row of electro-magnets, one for each key, is placed under the pneumatic valves that open the pallets. The armatures are attached to the pneumatic valves. When the key is depressed, the circuit is closed, causing the magnet to attract the armature, thus opening the pneumatic valve. When the circuit is broken, the pneumatic valve is closed instantly by a spring. The device for closing the circuit consists of the following parts: (1.) On the under-side of the key is a thin vertical strip of brass. (2.) A strip of wood passes horizontally across the keys, furnished with small brass buttons—two to each key—to which the wires from the battery are attached. When the key is depressed, the vertical strip of brass slides from the upper to the lower button, thus forming a metallic connection, and closing the circuit. A similar device is applied to the draw stops, pedals, combinations and couplers.

H. A. CLARKE,
Chairman of Committee.
RICH. ZEIKWER.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

—OF—

SECTION XXVII.

(SECTION IV, CLASS X, OF THE CATALOGUE.)

APPLICATIONS OF ELECTRICITY TO WARFARE.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE,
1885.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman.*

CHARLES BULLOCK,

THEO. D. RAND,

COLEMAN SELLERS,

WILLIAM H. WAHL.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXVII.—APPLICATIONS OF ELECTRICITY TO WARFARE.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXVII, on Applications of Electricity to Warfare.

Respectfully,

M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR: The Examiners in Section XXVII (on Applications of Electricity to Warfare), respectfully present the following report.

D. P. HEAP (*Ch'n*),
Examiners of Section XXVII.

PHILADELPHIA, *December*, 1884.

TREASURY DEPARTMENT,
OFFICE OF THE LIGHT-HOUSE BOARD,
Washington, November 21, 1884.

SIR:—I have the honor to submit herewith the report of Section XXVII on the applications of electricity to warfare. The exhibit of the Ordnance Department, U. S. N., is the only one containing appliances of this nature. As, however, search lights to be used either on the deck of a vessel or from shore would be useful in warfare, your committee has made a careful report of the best of those exhibited. As chronographs are used to determine the velocity of projectiles, there is included a description and plate of a target used in connection with them, possessing some novel features. The chronographs themselves come under the head of "instruments of precision," and are therefore not described in this report.

Respectfully submitted,

D. P. HEAP, Major of Engineers, U. S. A.,
Chairman Section XXVII.

BRUSH AUTOMATIC FOCUSING LAMP.

EXHIBITED BY THE BRUSH ELECTRIC LIGHTING CO.

This lamp is similar in principal to the well-known Brush lamp, the difference being that both carbons feed instead of one, the upper carbon about twice as fast as the lower. This is accomplished by means of a lever, the short arm of which is attached to the lower carbon, and the long arm to the upper carbon, when the arc becomes too short, the electro-magnet raises the upper carbon and by means of the lever lowers, at the same time, the lower carbon.

The length of the short arm of the lever can be changed so that the proportion between the length of the lever arms can be made to correspond accurately to the rate of the consumption of the carbons to which they are attached. Two guides through which the carbons pass near the focus assure their proper alignment. The whole apparatus is exceedingly simple, well and strongly made, and could be used in a reflector to advantage as a search light. The lamp exhibited is about 4,000 candle-power.

D. P. H.

BRUSH HAND FOCUSING LAMP.

This is the ordinary Brush lamp with the addition of a horizontal wheel by which the whole lamp can be raised or lowered, so as to bring the arc in focus; the upper carbon feeds, the lower is fixed. This lamp was specially designed for use in magic lanterns, in place of the oxy-hydrogen light and generally for laboratory use. It of course needs nearly constant attention to keep the arc in focus. The lamp is well and simply made, and is well adapted for the purpose for which it was designed. D. P. H.

STEAMSHIP PROJECTOR AND FOCUSING LAMP.

EXHIBITED BY THE UNITED STATES ELECTRIC LIGHTING COMPANY.

This consists of three principal parts, namely, the lamp, the parabolic reflector and the supporting frame. The lamp differs in this particular from the ordinary lamp made by this company; instead of only one, both carbons feed; this is accomplished by means of a cord passing over a small pulley which is attached to the lower carbon, the end of the cord being made fast to the circumference of a larger pulley connected with the feeding mechanism of the upper carbon, the whole being so arranged that the upper carbon will feed about twice as fast as the lower and thus the arc will remain in the focus of the reflector.

A device of this kind is necessary when a continuous current is used, as the upper carbon is consumed about twice as fast as the lower. If an alternating current be used the upper and lower carbons should have the same feed, in this case the two wheels mentioned would be of the same diameter. The parabolic reflector is contained in a metal drum with trunnions supported by the arms of the frame, the lamp is attached to this drum and moves with it. Two handles behind the drum allow it to be moved around a horizontal axis. To one trunnion is attached a handle which clamps the drum in any desired position; the opposite trunnion is hollow, and in it is inserted a piece of ground glass on which the light from the arc falls through a small hole in the reflector, this enables the operator to see that the arc is accurately in focus; a horizontal wheel below the lamp raises or lowers the whole lamp so that if the arc should get out of focus it can readily be brought

back, there is also a vertical wheel for imparting a horizontal motion to the lamp, either for bringing the arc into focus so as to concentrate the beam or for throwing it out of focus so as to disperse the light and cause it to illuminate a larger space.

The frame is of cast iron and is intended to be firmly bolted to the deck of the vessel, the upper part revolves around a vertical axis and can be clamped in any position, this motion with that of the drum before mentioned allows the light to be thrown in any direction. One man can manipulate the lamp and can readily make all the adjustments, which are within easy reach. The power of the arc lamp exhibited is about 7,222 candles; this, when concentrated in a beam by the reflector, would be greatly increased. D. P. H.

THOMSON FOCUSING LAMP.

Exhibited by the Thompson-Houston Electric Co.

This lamp is the ordinary Thomson lamp, so modified that both the upper and lower carbons feed in about the proportion of two to one. The modification consists in attaching a rack to the rod carrying the upper carbon; this rack engages a toothed wheel, on the same axis of this wheel and revolving with it is another toothed wheel of half the diameter of the first; this smaller wheel engages in a rack attached to the rod carrying the lower carbon—hence the upper carbon will feed twice as fast as the lower. (Figs. 1–3.)

Attention is drawn to the following peculiarity in this lamp: The rack is not fixedly attached to the carrier of the upper carbon, but is freely movable between stops *s. s.* (seen in Fig. 3) so that the carrier *R* has a slight independent vertical play between the stops and is lifted by the action of the clutch, when the arc is to be formed without imparting motion to the rack *M* and the lower carrier and carbon. The rack *M* is of sufficient weight to balance the rack-rod and carrier R^2 (Fig. 1) and its accompanying parts, so that no tendency to movement exists unless the carrier *R* and its parts add their weight to that of the rack *M* when the clutch *Y* is released.

The mechanism acts as follows: In Fig. 2, the carbons are shown in the reflector *Y* ready for use, when the clutch is lifted by the magnet system the slight play of the carrier *R* outside of the rack *M* allows the formation of the arc without any movement of the gearing—when

the clutch lowers to feed the carbons the weight of *R*, *F* and *E*, etc., is added to that of *M* and causes both carbons to feed at their proper rates by the rotation of the gear wheels. Should, however, the carbons over-feed from any cause and the carbons run too near together, there is at once a renewed lift by the clutch as at first without disturbing the gearing. Fig. 4, exhibits a perspective view of the Thomson Focusing Lamp. D. P. H.

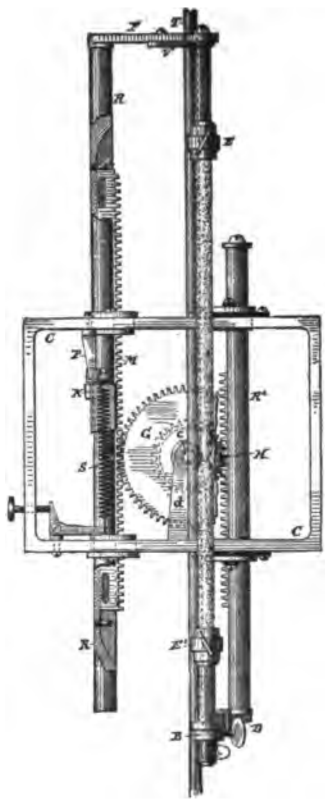


FIG. 1.—Thomson Focusing Lamp. (Details.)

The advantage of this device is that the magnets having but little weight to lift, can act promptly and preserve the electrical balance necessary to a steady light. The position of the arc during burning and the relation of the parts render possible a very compact lamp. It can readily be fitted to a projector the same as described under other systems. The details of the ordinary Thompson lamp are not

given here as they properly belong to another section. Drawings and photographs are, however, included for convenient reference.

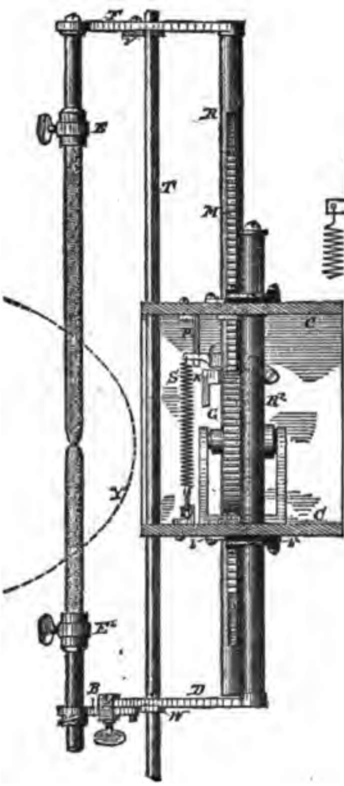


Fig. 2.

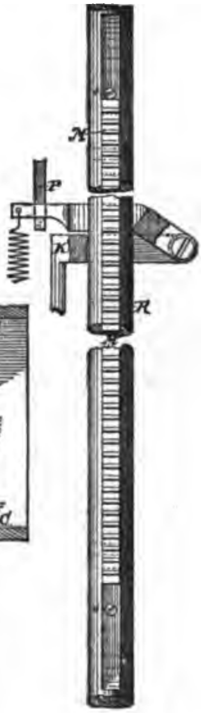


Fig. 3.

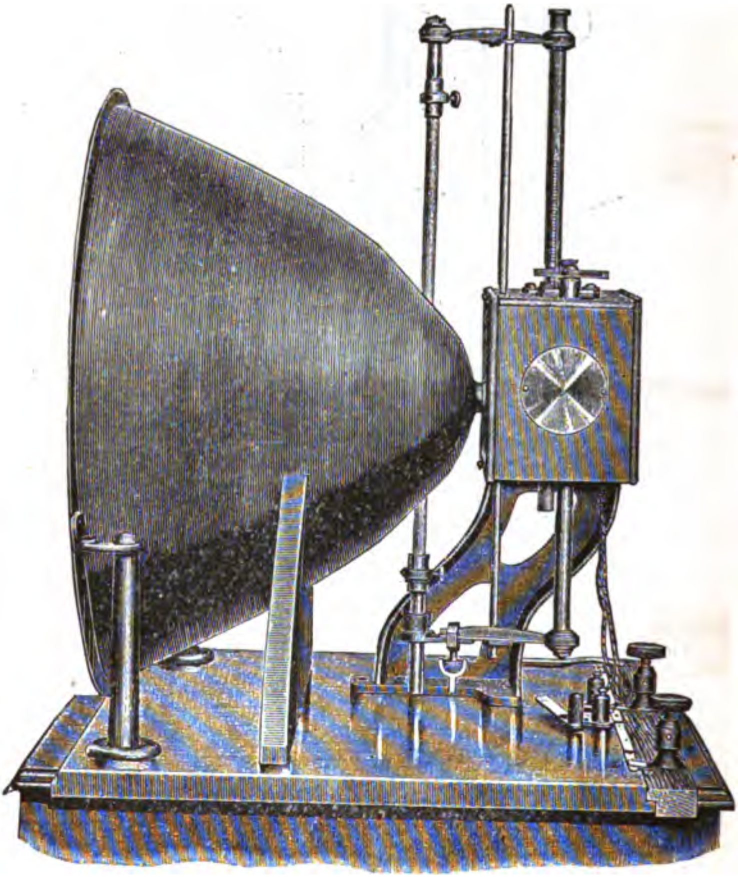


FIG. 4.—Thomson Focusing Lamp.

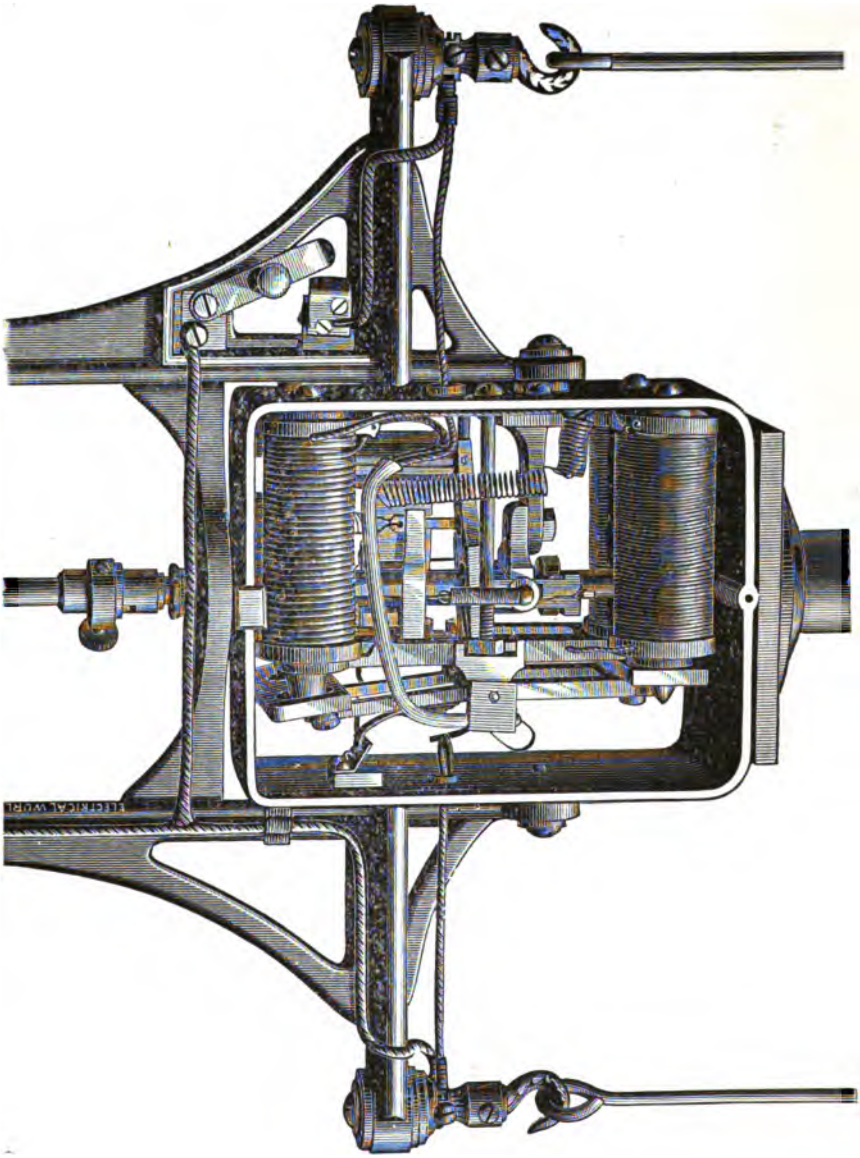


Fig. 5.—Mechanism of Thomson Arc Lamp.

THE MANGIN PROJECTOR.

(U. S. NAVY DEPARTMENT EXHIBIT.)

[NOTE:—The description of this projector is compiled from the reports of Lieutenant T. C. McLean, U. S. Navy, and of Major D. P. Heap, Corps of Engineers, U. S. A., on the International Exhibition of Electricity held in Paris in 1881. The plates are also taken from the same reports.]

Before the invention of this projector, the lenticular and the parabolic were used, the former is not only costly but also to some degree absorbs the light: the latter form is difficult to obtain with precision. It was these considerations which led Colonel Mangin to seek a new form, which he has happily found in a spherical glass mirror of special construction. In the ordinary spherical form, the spherical aberration interferes with its use when the light is projected to a distance, Colonel Mangin has ingeniously corrected this defect; he uses a glass mirror, the reflecting surface of which is on the convex side, thus the ray traverses twice the thickness of the mirror before taking its final direction. Now, these two surfaces are not parallel, the interior surface being a sphere having a different radius than the other, or in other words the mirror is a concavo-convex lens with the centre thinner than the edge.

The different thicknesses which the various rays have to traverse, according to the angle which they make with the axis, so modify them as to bring them rigorously parallel if the radii of the two surfaces of the mirror are in proper proportion. The Voltaic arc is peculiarly well adapted for use with such apparatus as it approaches most nearly the character of a luminous point. The lamp used is exceedingly simple and needs but little description in addition to the plates. It will be noticed that the carbons are inclined. This is because where a continuous current is used, the maximum intensity of the light is not in a plane perpendicular to the line of the carbons, but in one about 30° below. A small mirror, or sometimes a carbon plate is placed in front of the carbons to throw the light on the reflector. The cylindrical body of the projector is mounted on trunnions, and the trunnion supports are fixed on a cap which is so pivoted on the base of the apparatus that the beam of light may be thrown in any direction desired. Clamps are provided at the right trunnion and at the base pivot for retaining the projector in any position for steady direction. The holes in the

cylindrical body are for ventilation. The glass door is made in strips so that a crack at any one point will not extend through the whole.

The various details of the lamp and projector are clearly shown in the accompanying drawings.

Plate I, figs. 1 and 2 represents respectively front and longitudinal sectional views of

The Mangin Projector.

[Dimensions given in millimeters.]

A. Drum containing lamp and spherical reflector.
B. Spherical reflector.
C. Front of projector enclosed with vertical stripe of glass.
D. Supporting arms carrying drum.
E. Base of apparatus showing electrical connections.

Plate II, figs. 3 to 10 gives the details of hand lamp.

[Dimensions given in millimetres.]

Fig. 3. Shows electrical connection of wires from lamp to wires in base.

Fig. 4. Side view of hand lamp.

Fig. 5. Front view of hand lamp.

Fig. 6. Details of device for raising or lowering both carbons simultaneously.

Fig. 7. Device for giving the upper carbon a backward and forward motion by means of the eccentric pin *n*.

Fig. 10. Details of device for giving lateral motion to upper carbon.

THE McEVOY TORPEDO DETECTOR.

This is a modification of the induction balance. It consists of a sinker, which is a heavy case containing two coils of fine wire in separate circuits, a cable containing four insulated wires which are connected to both ends of the coils, and a box which holds two coils, each one of which is in series with one of the coils in the sinker, and connected to them by the four wires in the cable. The box is designed to be carried in a boat, from which the cable hangs. One of the coils in the box, and its corresponding coil in the sinker are in circuit with a small battery and an automatic circuit-breaker, which is also in the

box. The whole forms a primary circuit of which the secondary consists of the two other coils and a telephone receiver in circuit with them.

When now the current in the primary is closed, the intermittent currents in the primary coils induce currents in the secondary coils, but the secondary coils being wound in opposite drections, they can be so adjusted that the induced currents neutralize each other, so that no sound is heard in the receiver. If, now, the boat is pulled slowly through the water and the sinker is thus dragged along the bottom, no noise will be heard in the receiver unless the sinker come into proximity with some mass of magnetic metal, such as a torpedo case. In this event, however, the number of lines of force enclosed by the coils in the sinker will be greater than the number enclosed by the coils in boat, the induced currents from the former coils, will overpower those induced in the latter, and a humming noise will be heard in the receiver.

The apparatus shown at the exhibition did not seem to be sufficiently sensitive; but there seems no reason for believing that an apparatus on this principle could not be made very sensitive by using much larger coils and a very stiong battery.

[Here follows a description of McEvoy's Electro-Automatic Mine, taken from the report of Lieutenant T. C. McLean, U. S. N., on the Paris Electrical Exhibition of 1881. This the committee does not deem it necessary to republish.—Ed. Com.]

B. A. F.

Bradley A. Fiske, Lt. U. S. N.,
William H. Greene,
Horace W. Sellers.

D. P. HEAP, Major of Engineers, U. S. A.
Chairman Section XXVII.

Fig. 1.

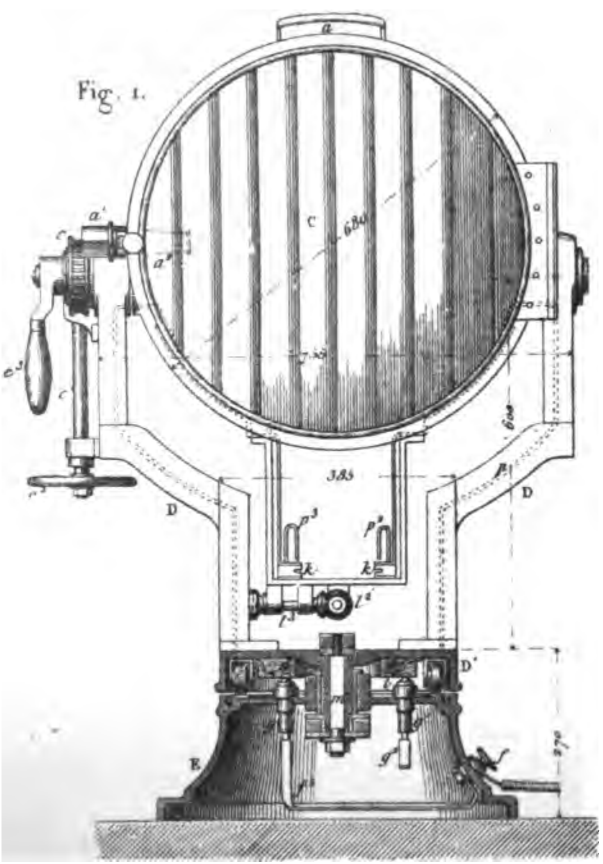
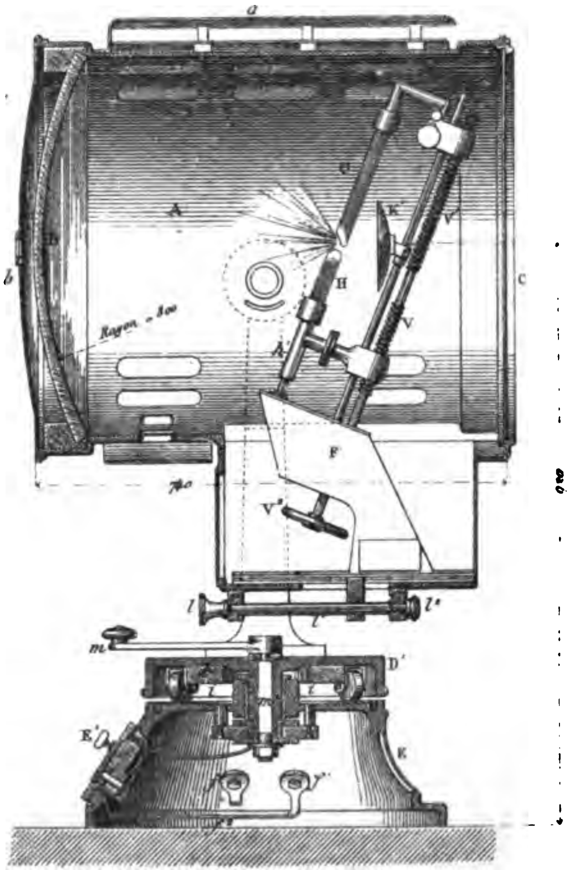
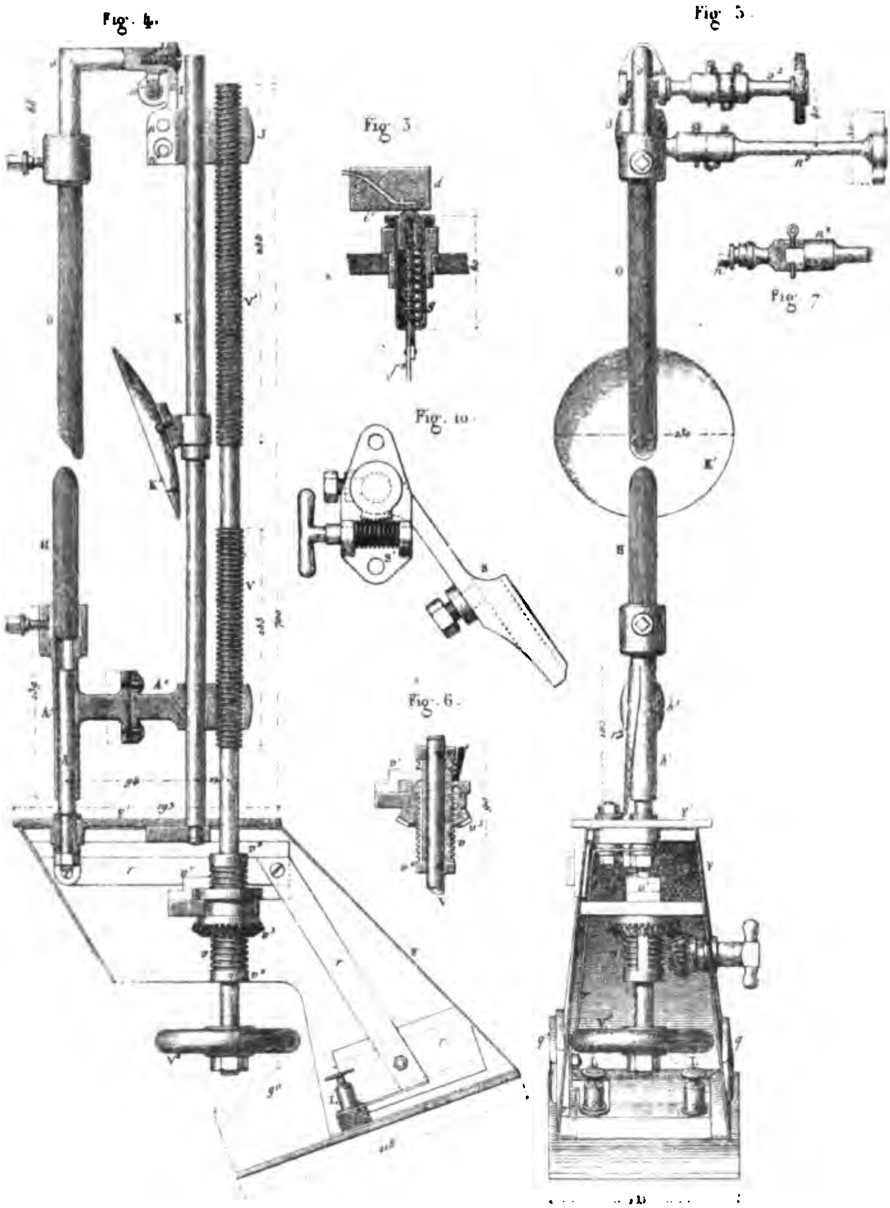


Fig. 2.



THE MANGIN PROJECTOR. (PLATE I.)



THE MANGIN PROJECTOR. (PLATE II.)

[DETAILS OF HAND LAMP.]

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

REPORTS OF THE EXAMINERS

OF

SECTION XXIX.

(SECTION VIII, CLASS I OF THE CATALOGUE.)

"Educational Apparatus," with which is Incorporated Section XIII, "Apparatus for High Electro-Motive Force."

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, MARCH, 1886.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1886.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,
CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL.

1884–INTERNATIONAL ELECTRICAL EXHIBITION–1884

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXIX.—EDUCATIONAL APPARATUS.
SECTION XIII.—APPARATUS FOR HIGH ELECTRO-MOTIVE FORCE.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I have the honor to transmit herewith the report of Examiners of Sections XXIX and XIII, on "Educational Apparatus," and "Apparatus for High Electro-Motive Force."

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, February, 1886.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—I herewith hand you the report of Section XXIX, on "Educational Apparatus."

Respectfully,
A. E. DOLBEAR,
Chairman Section XXIX.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—I herewith hand you the report of Section XIII, on "Apparatus for High Electro-Motive Force."

Respectfully,
J. B. DEMOTTE.
Chairman Section XIII

GREENCASTLE, IND., December, 1885.

REPORT ON EDUCATIONAL APPARATUS.

EXHIBIT OF JAMES W. QUEEN & CO.

The general exhibit of this company was of much greater variety than that of any other exhibitor, and embraced useful devices for illustration and demonstration in nearly the whole field of physics.

The attention of the committee was directed chiefly to the specific electrical apparatus useful for educational purposes, as distinguished from instruments of precision; which latter department was in the hands of another committee. A very large part of experimental philosophy is quite independent of the question "How much?" and in the dominion of electricity it is particularly the case that the phenomena may be developed, and the relations studied without any attempt towards quantitative results.

Messrs. Queen & Co. were instrumental in securing a large number of foreign exhibitors, whose apparatus was shown in the space allotted to them.

A part of many of these separate exhibits consisted of apparatus properly called instruments of precision, and referably going to that examining section. Because in many institutions of learning to-day, measuremental work of the highest grade is done, and it is difficult to draw a line between instruments adapted to such work and what is ordinarily understood by the term Educational Apparatus; and on the other hand, the skilful teacher is able to do some very fair quantitative work with instruments designed only for indications.

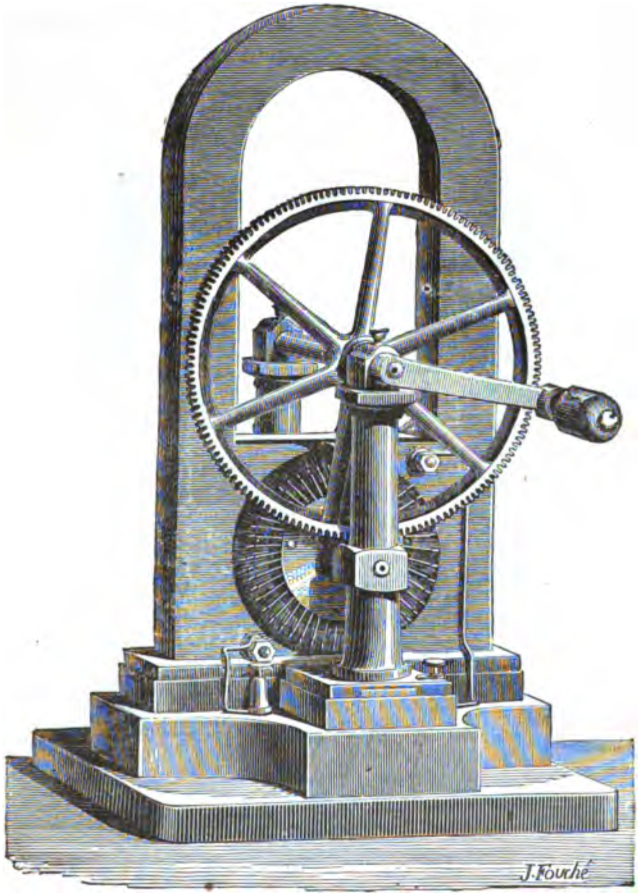
It has been thought best to incorporate into this report the special reports on hand dynamos, by Prof. W. A. Anthony, of Cornell University, and by Lieut. Murdock, U. S. A.

Queen & Co.'s Exhibition Catalogue contained upward of 1,600 numbers. The committee could not inspect them all but everything they specifically looked for, they found. The following they deemed worthy of special mention.

EDUCATIONAL APPARATUS BY BREGUET.

Gramme Machines.—The structure and principles of the Gramme machine are so well known that a description of them is not thought to be necessary here. They are compact, exceedingly

simple in structure, easily managed, and very efficient. A number of these of different sizes, and adapted to be run by hand or by the steam engine, were exhibited. The smaller ones to be run by hand

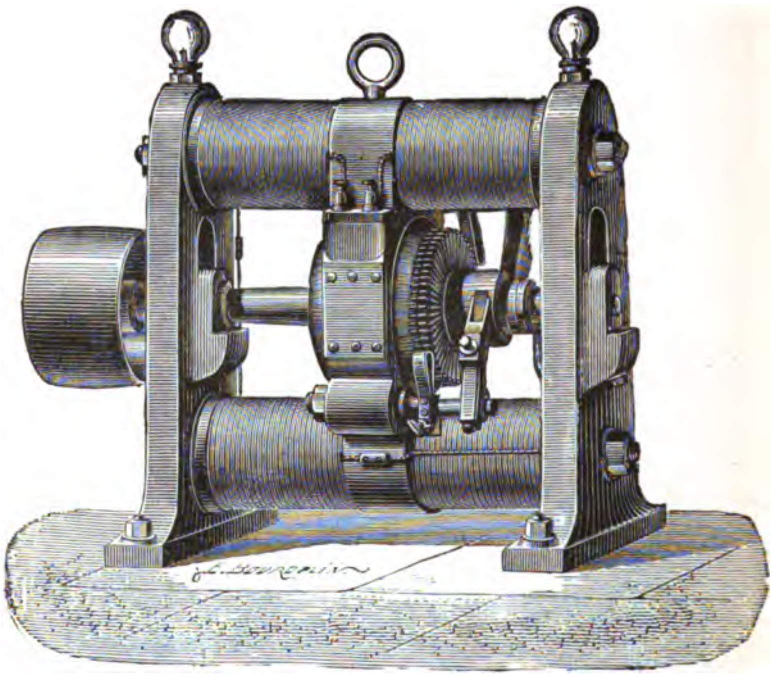


No. 16. Gramme Magneto-Electric Machine.

are provided with powerful permanent magnets to furnish the magnetic field, and such ones may be used as substitutes for a small galvanic battery, and a large number of experiments may be performed with the current from such a machine. The machine may have armatures wound with coarse or fine wire, or what is better, have both. One may then have a high electro-motive force, or a low electro-motive force, adapted to his needs. With the machine made for laboratory model and with thick wire armature, one may

produce about ten volts and two and one-half ampères current with a speed of 2,640 revolutions per minute.

With the fine wire armature, one may have about forty volts at the brushes, and a current of five ampères As the electro-motive force is proportioned to the speed, each machine has a numerical constant which, multiplied by the number of revolutions per minute, will give the electro-motive force.



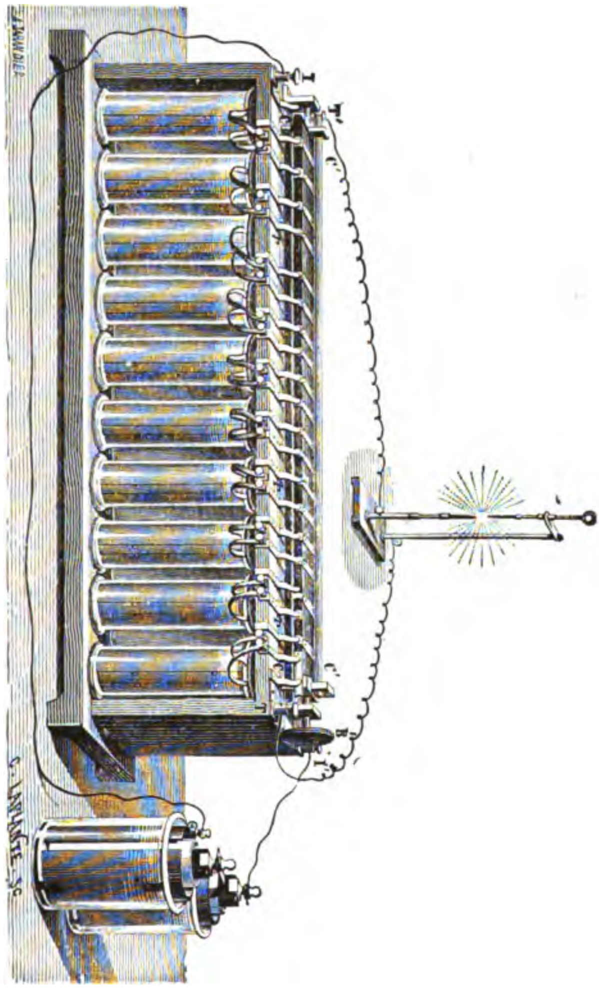
Gramme Machine. Type A.

The large machine, marked Type A, requires an engine of two or three horse-power, to run with any speed on a circuit. It is particularly well adapted to the needs of workshops, and of institutions of learning, for demonstrative requirements seldom exceed its capabilities. With a speed of 1,000 revolutions per minute, the electro-motive force is seventy-five or eighty volts, and the current strength about twenty-five ampères, while with a speed of 1,200 or 1,400 one may run three arc lights or twenty or thirty incandescent lamps. With lower speeds and less current all the demonstrative

work necessary for instruction may be done in a very much more satisfactory way than is possible with any kind of a galvanic battery.

The exhibit of the Maison Breguet included many other scientific instruments of value for educational purposes.

There was shown the well-known Serrin electric regulator and the Planté secondary batteries. Of these last, there was a set of

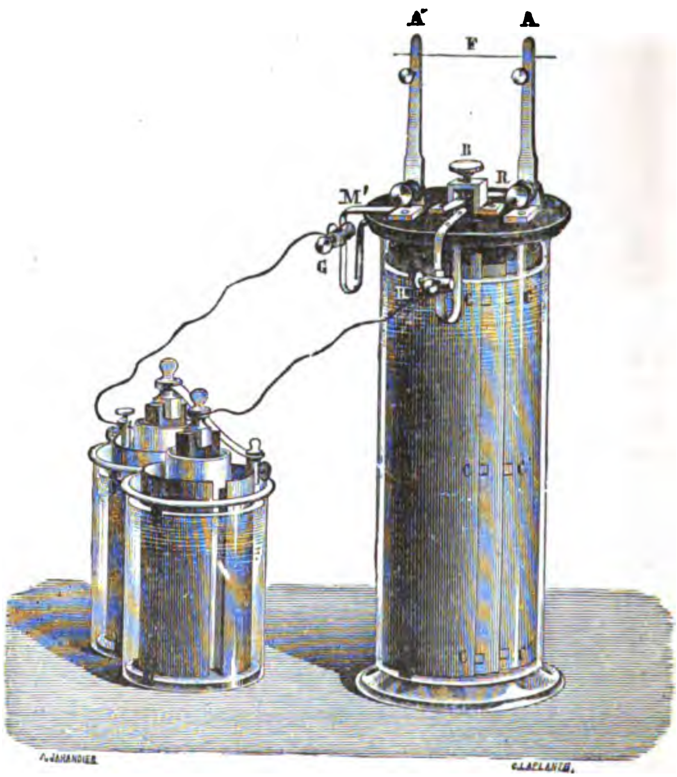


Set of Twenty Small Secondary Batteries.

twenty elements exhibited, and also several different sizes of single elements. These are useful batteries for class demonstration, and for general lecture experiments.

The rheostatic machine and battery of secondary couples, with zinc wire of M. Gaston Planté.

This machine is composed of fifty condensers in mica, joined to a Planté commutator by metallic spring blades, or springs, in such a manner as to be successively charged in quantity and discharged in tension. The two poles of the electric source which should charge the apparatus are joined permanently

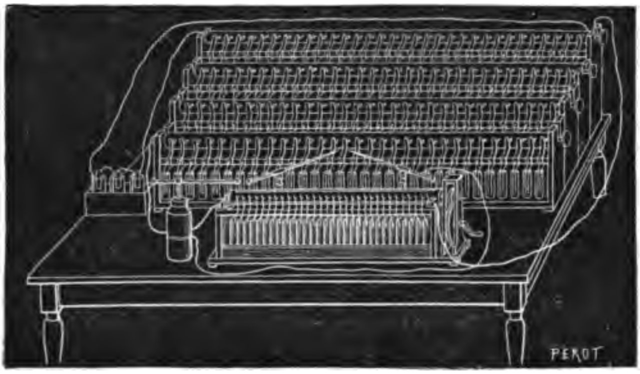


Planté's Secondary Battery.

to the binding screws *P P*, whilst the sparks burst out between the points represented in cut. This spark, or flash, is in proportion to the electro-motive force of the charge. Its length has a maximum for each apparatus, which maximum is determined by the construction.

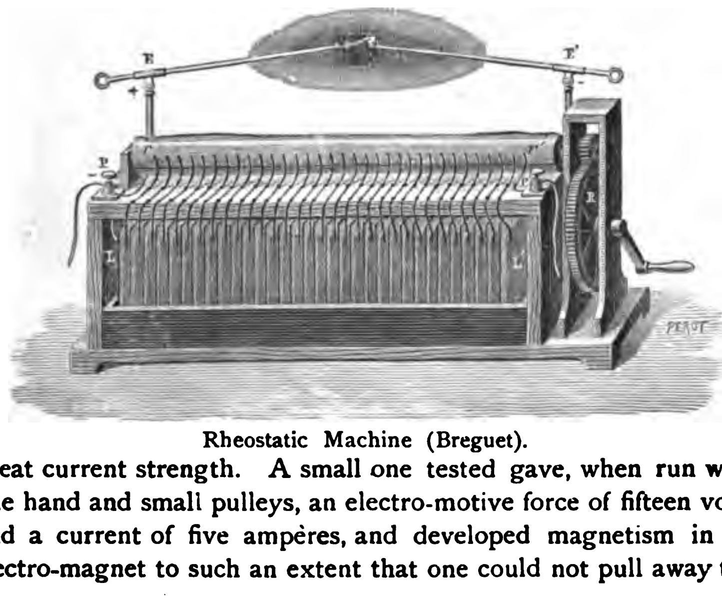
The complete battery is formed of 320 of these small elements, divided in four batteries of eighty couples each. These eighty

couples can be associated instantly by means of the commutator Planté, in quantity or in tension. These four batteries, laid out on shelves, one above the other, to put each couple in action are associated in quantity for the charge, and in tension for the discharge.



Rheostatic Machine (Breguet).

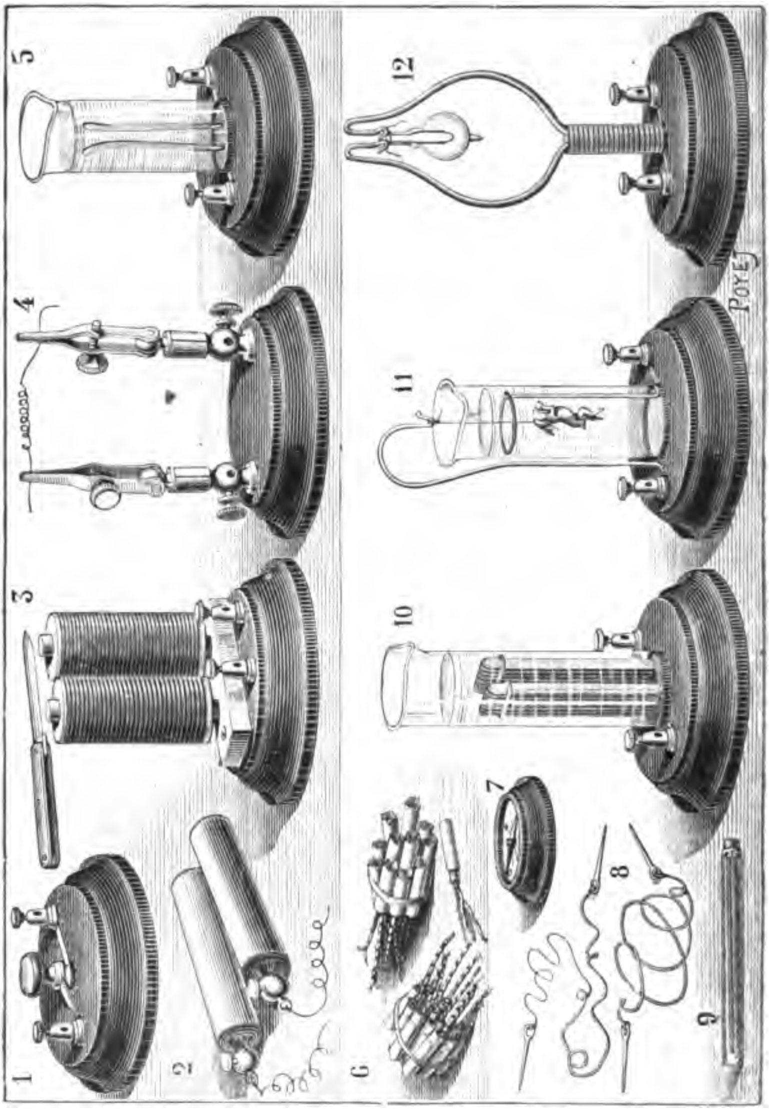
Apparatus by Gerard.—Dynamos of various sizes, to be run by hand or steam-power. These machines are very compact, and those to be worked by hand are good substitutes for batteries for the many experiments needing a tolerably steady current, but not



Rheostatic Machine (Breguet).

great current strength. A small one tested gave, when run with one hand and small pulleys, an electro-motive force of fifteen volts and a current of five ampères, and developed magnetism in an electro-magnet to such an extent that one could not pull away the

armature while a current was passing. These small hand dynamos of Gerard are intended for school work, and small incandescent lamps, electro-magnets, electric bells, fuzes for explosion, etc., form a part of the collection, all adapted to be run by the current generated by hand, and they work successfully.



Accessories to Small Gerard Machine.

In order to exhibit, with satisfaction, electrical phenomena, it is more than convenient, it is necessary, that the different pieces to be used should be adapted to each other, which is not always the case when pieces are obtained without regard to adaptation, as is often the case with school apparatus. Gerard, therefore, has a series of accessories for his machines, some of which are shown in the accompanying cut, which mostly tell their own story, and show to what a variety of experiments the machine may be put.

(See reports following on hand dynamos, by Professor Anthony and Lieutenant Murdock.)

It is not an uncommon thing for comparisons to be made between hand dynamos and galvanic batteries, in which the statement is that a certain machine is equal to two or five or ten Grove cells. Such a statement is very indefinite indeed, and not a few have bought such machines expecting to get much more from them than is mechanically possible. The following exposition of the relations between such machines and the work spent on them may help one to a more correct idea.

Suppose a man to exert a constant power equal to one-tenth of a horse-power in running a dynamo in a circuit in which the total resistance is R ohms. To find the electro-motive force produced: the horse-power for a certain current is $HP = \frac{E\,C}{746}$

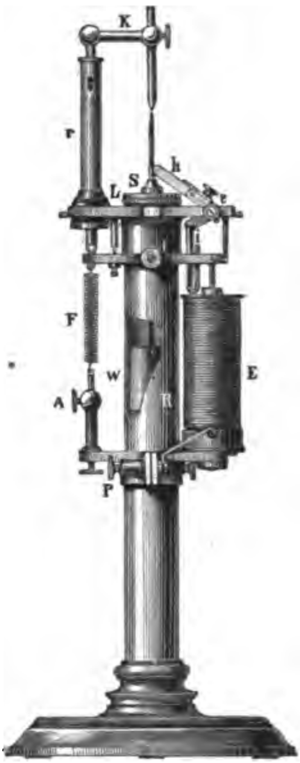
$$\text{As } C = \frac{E}{R} \therefore HP = \frac{E^2}{746\,R} \therefore E = \sqrt{HP \times 746\,R}.$$

If $HP = \frac{1}{10}$	$R = 2$	$E = \sqrt{149 \cdot 2} = 12 \cdot 2$	volts.
" " "	$R = 5$	$E = \sqrt{373} = 19 \cdot 3$	"
" " "	$R = 10$	$E = \sqrt{749} = 27 \cdot 3$	"
" " "	$R = 50$	$E = \sqrt{3730} = 61 \cdot$	"
" " "	$R = 100$	$E = \sqrt{7460} = 86 \cdot 4$	"

Now, one-tenth of a horse-power is more than most persons can exert except for a brief time, but the current strength for sixty-one volts and resistance fifty ohms will be but 1·22 ampères. How much of this energy will be available will depend upon the ratio of the external to the internal resistance of the machine. Hence the necessity for having the apparatus to be used with such a hand dynamo, *adapted to it.*

EXHIBIT OF C. & E. FEIN, OF STUTTGART.

Dynamos for hand working. These were conveniently and neatly mounted upon tables, and provided with numerous attachments suitable for use in the lecture room. The exhibited set of accessories was more complete than any other exhibit of similar kind, and embraced nearly everything which a teacher would want in teaching this subject. The pieces were generally of a larger size than those by other makers.



Fein Arc Lamp.

Fein Electromotor.

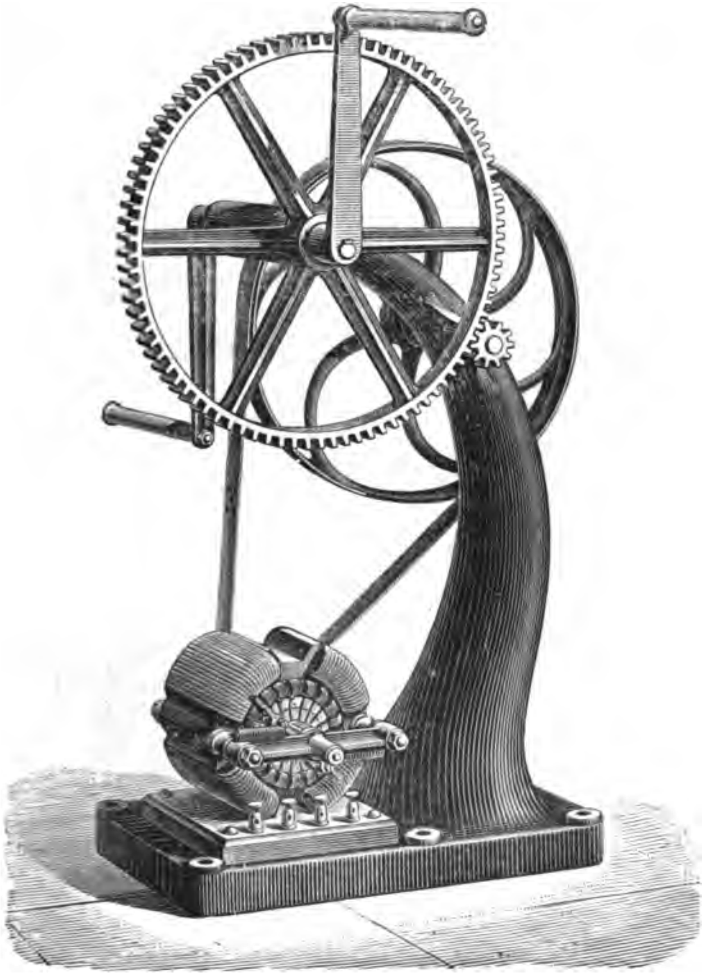
The following pieces were specially noticed:

Voltameter, electro-magnet, galvanoplastic apparatus, electromotor induction coil, incandescent lamps, arc lamps, Geissler tubes, voltameter and ampèremeter. These appeared to be all well made and adapted to their specific uses.

(See report on hand dynamo of Fein, by Lieut. Murdock.)

EXHIBIT OF A. DE MERITENS, OF PARIS.

His dynamos are made in large models for supplying currents for electric lights, or for any other purpose, and require some motive-power as steam or water; and small models which may be

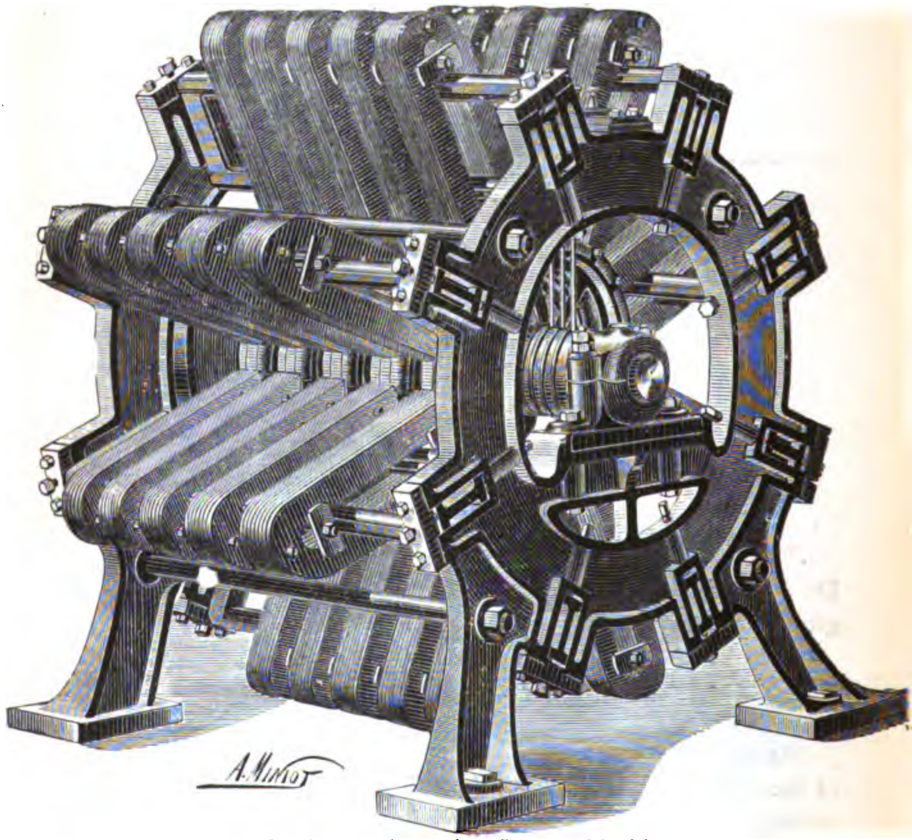


De Meritens' Machine. Model C.

run by hand-power, and suitable for most lecture-table experiments. The cut represents such a machine mounted to be driven by either one or two persons, and is capable of producing an arc light. The machine is so arranged that armatures with different

resistances may be readily substituted, and thus adapted to different kinds of electrical work. The dynamos are particularly compact and efficient. Several are already in use in colleges in the United States.

There was also exhibited a large magneto-electric machine, by De Meritens, driven by an engine. It was an alternate current machine, and was used to light Queen & Co.'s exhibit, with Jablochkoff candles, and was an interesting machine for both



De Meritens' Alternating-Current Machine.

structure and function, as such machines are not used to any extent in this country, and the Jablochkoff candles requiring such alternating currents, are now-a-days mostly displaced by the more modern arc and incandescent lamps. This machine, marked Model A, was capable of lighting thirty Swan lamps.

Jablochkoff Candle.

There were various interesting accessories to the exhibit of De Meritens,—brackets, commutators, Jablochkoff candle holders, globes, etc., exhibiting both taste and mechanical skill.

(See Prof. Anthony's report on De Meritens' hand dynamo.)

TEST OF HAND DYNAMOS.

At the request of Messrs. James W. Queen & Co., I tested some of the hand dynamo machines for which they are agents. The attempt was made at first to use ordinary instruments, tangent and potential galvanometers, but it was found that the irregularity of the current prevented any accurate observations, and it was impossible to turn the cranks with sufficient regularity to produce a current which could be measured. The plan was then adopted of measuring the external resistance, and determining the current by a Deprez ammeter. The resistances used were of German-silver,

several being attached to the frame of one of the Fein machines. Three others, each of about six ohms resistance, were used.

It was thought that the best method of testing would be to obtain as far as possible, the maximum output of the machines, and the observations were therefore made under these conditions. The crank was turned as rapidly as possible, and the maximum current was observed. The results thus obtained, were of course higher than could be kept up for any length of time, but in most of the machines the test was also made under the usual working conditions.

The two when combined give the maximum which can be obtained, and the ordinary work which can be depended on.

The resistances heated very slightly, owing to the short time that the current was passed through them.

The ammeter used had been calibrated at the test house and found to be in general in excess about three per cent. This correction was applied to all observed currents. Currents below two and one-half ampères were measured by another ammeter, graduated to tenths of an ampère. No correction was applied to the readings of this instrument.

The above applies to all machines tested.

Two machines were exhibited by C. & E. Fein, the No. 3 and No. 10.

The No. 3 gave the following results:

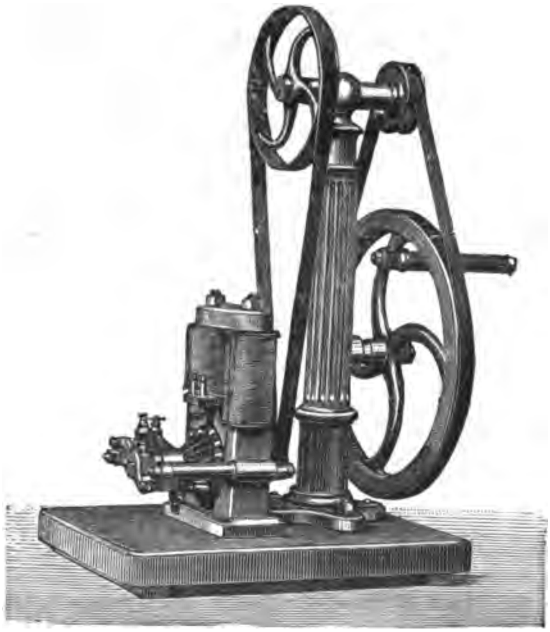
Armature Resistance,	35
Field "	26
Total,	61 legal ohms.

Current.	External Resistance.	Difference of Potential.	Total Resistance.	E M.F.
10·5	·9	9·45	1·5	15·75
10·1	1·1	11·1	1·7	17·2
8·9	1·5	13·3	2·1	18·7
7·6	1·85	14·1	2·45	18·6
6·5	2·8	18·2	3·4	22·1
3·7	5·0	18·5	5·6	20·7
1·65	7·3	12·0	7·9	12·9
1·25	8·9	11·1	9·5	11·9
·50	14·4	7·2	15·0	7·5

The results may be taken as the best capable of being obtained by a man of average strength. The best continuous working is about one-half the above E. M. F. for any given resistance.

The makers make the following statement in regard to the capacity of this machine.

It is capable of melting a steel wire 250 mm. long and ½ mm. thick. It will make a platinum wire of 500 mm. in length, and ⅕ mm. thick, incandescent. It will evolve 150 cubic cm. of

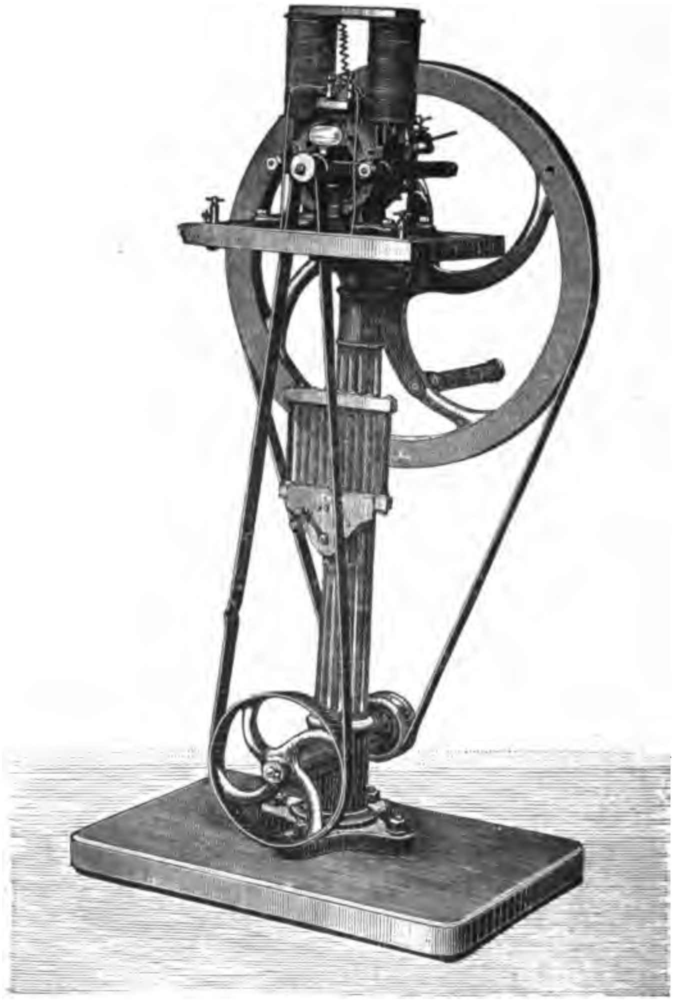


C. & E. Fein's Hand Dynamo. (No. 3.)

water gases per minute. It will deposit 280 milligrams of copper per minute.

The arrangement of this machine appears to be good, and quite compact, with but small weight for its power.

The second machine, exhibited by C. & E. Fein, was a No. 10, Model 1 b. This machine was the most powerful one tried, and was operated by two men on separate cranks. It has attached to its frame a set of German-silver resistances, which affords the means of modifying the external circuit at will. Some difficulty was found at first in exciting the field, but when the machine once



C. & E. Fein's Hand Dynamo. (No. 10.)

worked it gave very good results. The same method was pursued in obtaining the maximum output. The results were as follows:

Armature resistance, ...	6·32
Field "	8·82
	15·14 legal ohms.

	Current.	External Resistance.	Difference of Potential.	Total Resistance.	E. M. F.
Maximum work with two men.	4·9	·9	4·4	16·0	78·4
	4·8	1·1	5·3	16·2	77·8
	4·9	1·5	7·3	16·6	81·3
	4·0	8·9	35·6	24·0	96·0
	3·7	15·7	58·1	30·8	114·0
	3·6	22·3	80·3	37·4	134·6
	3·3	28·6	94·4	43·7	144·
Continuous working, two men.	2·0	28·6	57·2	43·7	87·4

As illustrating the uses of machine No. 10, the maker states that it will melt a steel wire 1 metre long and 0·15 mm. thick. It will make incandescent a platinum wire 2 metres long and 0·15 mm. thick, and it evolves 150 cubic centimetres of gas per minute. It will deposit 250 milligrams of copper per minute.

This machine is of such capacity as to admit of demonstrating almost anything which can be expected of a dynamo machine. As it is capable of being worked by two men, its output is very large, and as seen by the figures of the test, it would bring to normal incandescence for a short time five ordinary Edison lamps, and would maintain several lamps of low potential, when worked continuously by two men.

The preceding machines are made wound with either coarse or fine wire. No. 3 machine tested, was wound with coarse wire, and No. 10 with fine wire.

Another machine tested was a Magneto-Gramme machine, from the Maison Breguet. It differed materially from the others apart from its being a magneto machine, in having a very small internal resistance, which would adapt it to a very different class of experiments.

Current.	External Resistance.	Difference of Potential.	Total Resistance.	E. M. F.
10·4	·95	9·88	1·01	10·50
9·2	1·15	10·58	1·21	11·13
7·1	1·55	11·00	1·61	11·43
5·4	1·85	9·99	1·91	10·31
4·7	2·75	12·92	2·81	13·21
2·4	5·05	12·12	5·11	12·26
1·75	6·40	11·20	6·46	11·31
1·30	7·90	10 27	7·96	10·36

No attempt was made to preserve a constant speed. One man turned the crank as rapidly as possible, and the maximum current was noted.

No. 2, A. Gerard Dynamo-Electric Machine.

Another machine tested was the Gerard, laboratory model, No. 0, with pulley and crank. This showed much less power than the others, being tested in the same way, with the following results:

Armature resistance,	1·32
Field "	4·93
Total internal resistance,	6·25

Speed.	Current.	External Resistance.	Difference of Potential.	Total Resistance.	E. M. F.	
2,600	3·5	·85	3·0	7·10	24·90	Maximum.
2,700	1·4	7·15	10·	13·4	18·80	"
3,500	1·0	13·75	13·8	20·0	20·0	"
3,200	·5	20·55	10·28	26·8	13·4	"
2,300	·7	7·15	5·	13·4	9·4	Easy working.
1,900	·3	13·75	4·1	20·0	6·0	"
	·25	20·55	5·1	26·8	6.7	

Reported by
J. B. MURDOCK.

Report upon Small Machines (dynamos), submitted by James W. Queen & Co., and Tested at the Physical Laboratory of the Cornell University, in January, 1885.

APPARATUS USED.

(1.) *Power Measurements.*—It was at first proposed to place the machines on a small Brackett cradle, but, as the adjustment consumes considerable time, it was thought best to use, as a motor, a Gramme machine, constructed ten years ago at the University, and which is mounted permanently on a very delicately balanced cradle. Having at hand a ten-light Weston dynamo, used for lighting the University campus, it was easy, using this as a generator, to obtain from the Gramme, as a motor, any power required, up to five or six horse-power. The Weston ten-light machine was provided with an adjustable resistance for the field circuit, which gave the most complete control of the current generated, and, therefore, of the speed of, and energy transmitted

by, the Gramme. Under these conditions, the Gramme was a very easily managed and exceedingly delicate transmitting dynamometer. The speed of the Gramme was indicated continuously by a Buss "Tachymeter," but was also frequently taken by a speed counter, as well as the speed of the machine under test.

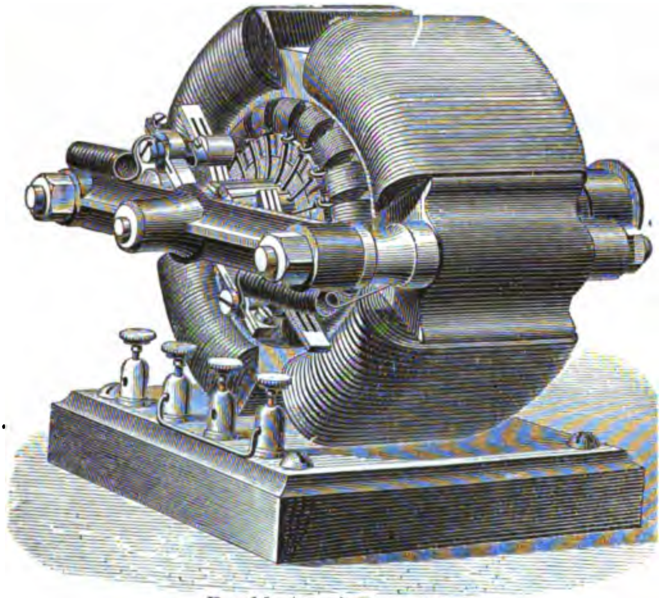
(2.) *Current Measurements.*—The currents were measured by a tangent galvanometer, whose conductor was a turned brass ring, fifty centimetres diameter, and a Thomson graded galvanometer. As H was not accurately known for the position of the tangent galvanometer, the constants of the instruments were determined by the copper voltameter. In the experiment for this purpose, two voltameters were placed in series, and the current continued for 100 minutes. Readings of the galvanometers were taken every four minutes. The extreme deflections were $40^\circ\ 24'$ and 41° for the tangent, and 31·6 and 32·7 for the Thomson. The deposit of copper was, in one cell, 10·477 grammes; in the other, 10·479 grammes; giving for the tangent galvanometer, 6·15; for the Thomson galvanometer constant, ·1644.

(3.) *Resistance Measurements.*—Resistances were measured by means of a dial pattern resistance box, by Elliott Brothers, adjusted to B. A. ohms. Resistances have not been reduced to legal ohms. The machines were run on a dead resistance of German-silver wire wound on a reel, and so connected that it formed one branch of a Wheatstone's balance, the other branches of which could not be appreciably heated by the current. By this arrangement, the resistance could be measured at any time while the current was flowing.

(4.) *Potential Measurements.*—The potentials between the terminals of the machines were measured by means of a Thomson potential galvanometer checked by an Ayrton and Perry voltameter. The constants of both these instruments were determined at the same time as the constants of the current galvanometers, by noting the deflection when they were connected to each side of the German-silver wire, whose resistance was determined while the current was passing by the means described above. In these measurements the power may be considered accurate to about $\frac{1}{100}$; current to about $\frac{1}{100}$; resistance to about $\frac{1}{300}$; potentials to about $\frac{1}{100}$.

The readings of the various instruments during any test were generally very constant. If any considerable variations occurred,

the test was repeated. Computations have been made independently by two persons, and it is believed that the results given are free from errors. In the tests of the machines, they were run at what was supposed to be the normal speed for some time, until instruments gave uniform readings, then readings were taken each minute for ten minutes. The resistance in the external circuit was then changed and another set of readings taken. Below are given the general results of the observations:



De Meritens' Dynamo.

Small De Meritens' Machine.—Shunt wound, armature of the Gramme type.

Weight of machine, ... 68 pounds.
Resistance of armature, ... 1·36 ohms.
" " field, ... 70·7 "

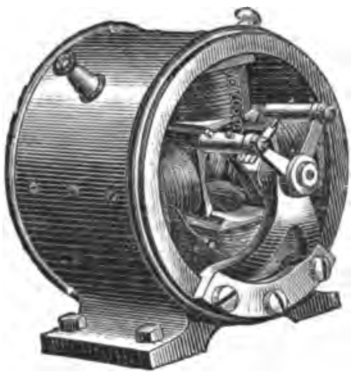
Current $= C.$	Potential at Terminals $= E.$	External Resistance $= R.$	Energy in External Circuit $= CE.$	Power given to Machine $= W.$ (Watts.)	Commercial Efficiency $= \frac{CE}{W}$	Revolutions per Minute.	Power Consumed HP.
6·88	49·4	7·18	339·9	686·5	49·5	3,240	·92
6·54	37·1	5·67	242·6	553·9	43·8	3,200	·74
5·56	21·8	3·9	121·2	401·3	30·2	3,300	·54

It will be noted that this machine gave the greatest current with the greatest external resistance. The strength of field therefore diminished as the external resistance diminished. Possibly, better results as to efficiency might have been obtained with a still greater resistance.

The machine worked a Foucault lamp very well, but in order to start the lamp it was necessary to carefully separate the carbons by hand, as, with the small external resistance existing when the carbons were in contact, the machine would not excite itself.

NO. 230. CATALOGUE OF QUEEN & CO.

Small Gerard Machine, No. O⁵.—Shunt wound, armature of four pole pieces projecting radially from the axis. On each pole piece was a coil of wire. The commutator flashed badly at high speeds. Twenty-five hundred revolutions per minute was the highest speed it could safely run.



Gerard Dynamo Machine. (No. o^5.)

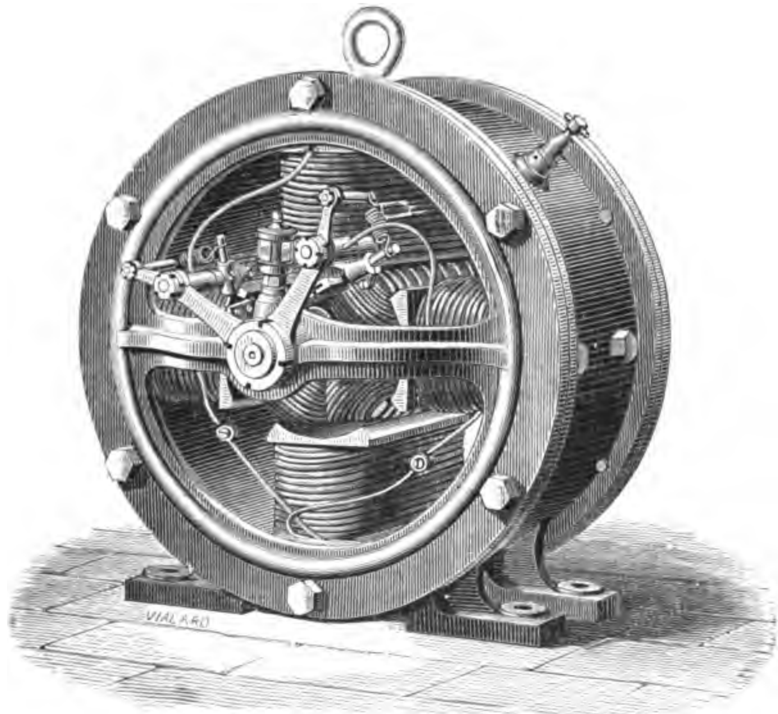
Weight of machine, ...	47 pounds.
Resistance of armature, ...	·199 ohms.
" " field, ...	17·88 "

Current — C.	Potential at Terminals — E.	External Resistance — R.	Energy in External Circuit — C E.	Power given to Machine — W. (Watts)	Commercial Efficiency — $\frac{C\,E}{W}$	Revolutions per Minute.	Power given to Machine in HP.
4·09	29·04	7·1	118·8	381·2	31·2	2,350	·511
5·33	31·08	5·85	165·7	433·3	38·2	2,590	·581
7·33	28·62	3·9	209·8	433·3	48·4	2,500	·581
7·73	21·8	2·82	168·5	426·4	39·5	3,330	·572
Brushes readjusted and tension of springs increased.							
5·154	36·6	7·1	188·6	556·3	33·9	2,670	·745

Large Gerard Machine No. 3.—Construction similar to small machine.

Weight, ... 327 pounds.
Resistance of Armature, ... ·24 ohms.
" " Field, ... 11·96 "

Current. $C.$	Potential at Terminals. $E.$	External Resistance. $R.$	Energy in External Circuit. $CE.$	Power given to Machine. $W.$ (*Watts.*)	Commercial Efficiency. $\frac{CE}{W}$	Revolutions per Minute.	Power given to Machine in $HP.$
10·76	80 66	7 94	867·9	2,585	33·6	1,356	3·47
10·39	71·3	6·86	740 8	2,443	30·3	1,390	3·27



Gerard Dynamo Machine. (No. 3.)

To determine how much of the loss in this machine was due to friction and how much to induced currents in the mass of the mag-

nets and armature, the brushes were thrown back and the machine driven at the same speed as in the above experiments. When the field was unmagnetized the power required was 147 watts = ·2 horse-power.

When field was magnetized by another machine having a potential of fifty-four volts, about three-fourths the potential of the Gerard machine, when magnetizing its own field, the power consumed was 830 watts or 1·11 horse-power.

In the circular describing the above machine, the normal speed was given as 1,600. In my experiments, at any speed above 1,400, the flashing at the commutators was so great as to endanger the machine. Below 1,400 there was no flashing and the machine ran quite smoothly.

WILLIAM A. ANTHONY.
Profr. of Physics, Cornell University.

Report upon Small Motors Tested at the Physical Laboratory of the Cornell University, in January, 1885.

These motors were submitted by James W. Queen & Co. from their exhibit at the Electrical Exhibition. They were a Griscom motor, a small motor of English manufacture, name not given, and an Ayrton & Perry motor. The power measurements of the first two were made by mounting the motor on a small Brackett cradle and causing it to drive a small machine which offered a resistance that could be varied at pleasure.

Current was measured by the Thomson current galvanometer, its needle in the most sensitive position, and potential by Siemens torsion galvanometer. The constants of these instruments were determined as described in the report on dynamos.

Griscom Motor.—

Weight, ... about 2½ pounds.
Resistance of field, ... ·616
" " armature, ... ·395

C.	*E.*	*E C.*	*W.* in Watts.	Eff.	Revolutions per Minute.	*W.* in *HP.*
3·81	7·84	29·87	6·86	23·	2,740	·0092
4·28	10·80	46·22	14·84	32·1	5,100	·0199
4·25	10·74	45·64	16·	35·	4,720	·0214
4·57	10·17	46·48	14·21	30·6	3,780	·0191

In this table and those that follow—

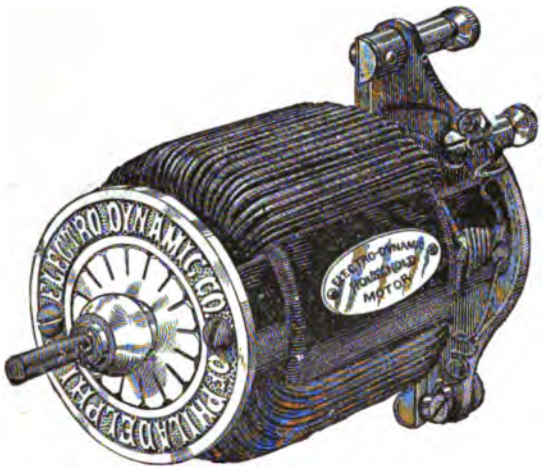
C = current through motor in ampères.

E = difference of potential between terminals.

$C\,E$ = electrical energy supplied to motor in watts.

W = work delivered by motor in watts.

The other columns explain themselves. In the first experiment recorded above, the potential 7·84 volts, was supposed to be less than the normal potential for the motor. In the subsequent experiments a higher potential was therefore used.



Griscom Motor.

The motor ran during all the experiments very smoothly without sparking at the commutator, and without undue heating.

NO. 353, CATALOGUE OF QUEEN & CO.

S. P. Thompson Motor.—

Weight, ...

Resistance of field, ... ·47 ohms.

" " armature, ... ·373 "

C.	*E.*	*E C.*	*W.* in Watts.	Eff.	Revolutions per Minute.	*W.* in *HP.*
5·33	9·664	51·51	13·55	26·3	2,333	·0182
4·74	10·29	48·77	13·19	27·0	3,360	·0177
4·11	11·49	47·22	19·72	41·8	4,320	·0264
3·865	8·74	33·78	13·50	40·	3,000	·0181

Some trouble was experienced in keeping the brushes of this motor in the best order. It was only by frequent readjustment that so good work, as is shown by the above table, was obtained.

A commutator and brushes, well constructed, would make of this a very useful motor.

NO. 322, CATALOGUE OF QUEEN & CO.

The Ayrton & Perry Motor, submitted by Queen & Co., was tried, but before any considerable power could be obtained from it, the commutator caught fire and made it necessary to stop the machine. It was taken apart, put in the best order possible, without reconstructing it, and tried again. Again the commutator took fire, before anything like the capacity claimed for the motor had been reached. Two similar motors, belonging to the University, had been tried some months before with similar results. The commutator of one of these, said by the makers to be good for a potential of 100 volts, had been partly reconstructed in the University workshop. The spaces between the commutator strips had been filled with insulating material and the brushes remodelled. The armature also had been carefully balanced.

In this condition it was a far better machine than as it came from the makers. It was tested in place of the machine submitted by Queen & Co., and the results are given in the table below, as showing the best that can be expected from this motor, without a radical change in its construction. A higher electro-motive force and higher speeds were tried, but with these there was a continuous flame at the commutator.

Weight of motor, ... 38 pounds.
Resistance of field, ... 0·57 ohms.
" " armature, ... 1·92 "

C.	*E.*	*E C.*	*W.* in Watts.	Eff.	Revolutions per Minute.	*W.* in *HP.*
8·34	59·75	498·32	141·9	28·5	1,500	·19

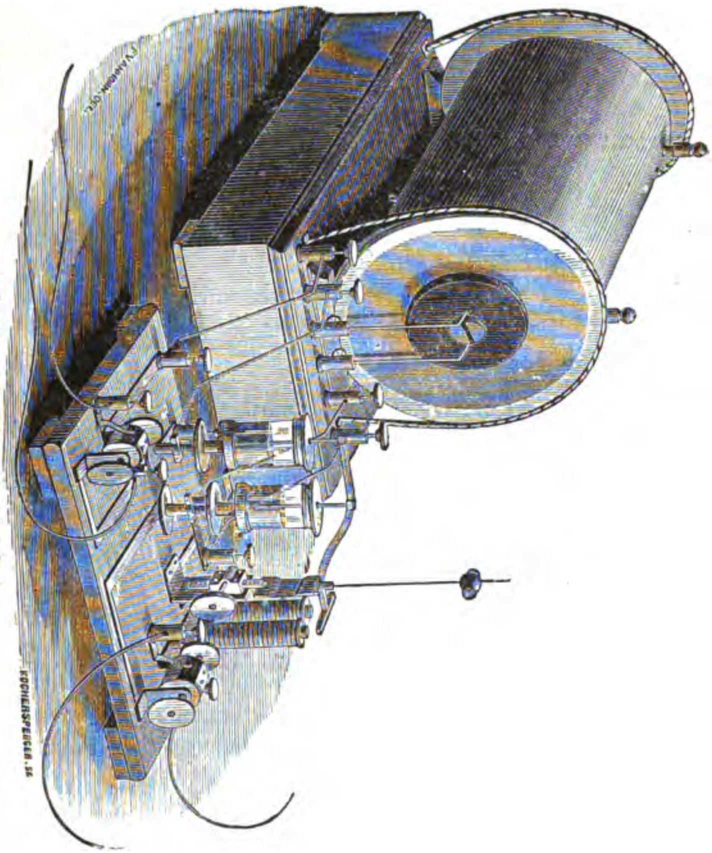
It should have been stated that the power delivered by this motor was measured, by making it drive a dynamo mounted on a Brackett cradle. The current of this dynamo could be perfectly controlled and, therefore, the power which it absorbed could be regulated at pleasure.

WM. A. ANTHONY,
Profr. of Physics, Cornell University.

EDUCATIONAL EXHIBIT OF J. CARPENTIER, OF PARIS.

J. Carpentier is the successor of the renowned Ruhmkorff, and the apparatus exhibited was in every way creditable for both manufacture and performance. The variety was great, and the following pieces were especially noted.

A large inductorium, capable of giving a spark in air of about twenty inches in length. The primary wire of this coil was formed of 403 turns of copper wire, 2·5 mm. in diameter, and having a

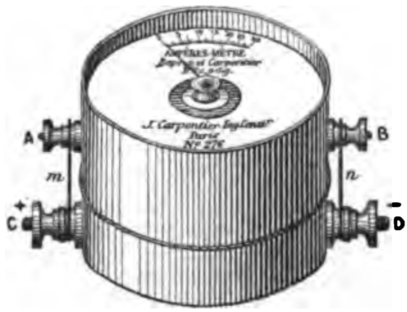


Induction Machine (Carpentier).

resistance of ·25 of an ohm. The secondary wire consisted of 102,500 turns of No. 34 copper wire, equal to about thirty-seven miles, and had a resistance of 58,000 ohms. It required a current of about twenty-five ampères in the primary to give a spark twenty inches long. It could be worked with slow or rapid vibrators, which were mounted upon the base or either side of the coil.

Voltameters and ampèremeters, of Carpentier and Deprez pattern. These, aside from being as accurate as others, are considerably cheaper.

Electrometer of Mascart.



Ampèremeter (Carpentier.)

Deprez electric motors.

Apparatus, of Melloni, with many accessories, and the Clamond thermopiles, which give with a gas flame an E. M. F. of about one-fiftieth volt per pair.

APPARATUS OF EDELMANN.

The most of the apparatus exhibited by this maker was intended for accurate electrical measurements and original research. Some of the voltameters and ammeters for student's use are cheap, but good. A Wiedemann galvanometer was used in the test house of the Exhibition.

The attention of the committee was called to Edelmann's "Physikalisches Arbeitsstatif" or universal stand with heavy tripod. This is a very neat and convenient laboratory instrument, and is supplied with a great number of clamps and pincers, and attachments or fitting up apparatus in scientific lectures. Edelmann also exhibited quite a collection of reading telescopes, galvanometers, and a very neat model of Wheatstone's bridge, after von Beetz.

APPARATUS OF ELLIOTT BROTHERS, LONDON.

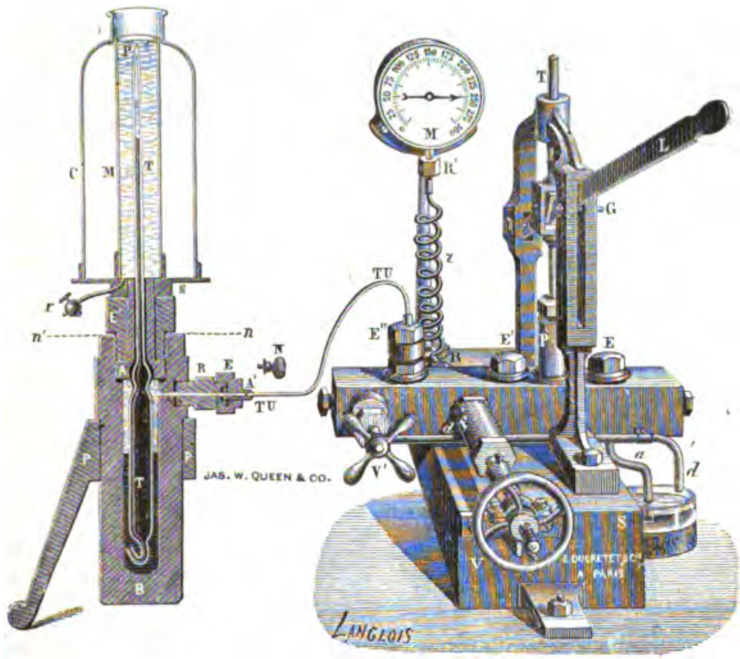
The instruments made by this house are too well known to require specification here. All the apparatus necessary for electrical measurements, Thomson reflecting galvanometer, Wheatstone bridges, Clarke's standard cells, condensers, electrometers, keys, etc., all accurate and well made, were exhibited.

C. J. Simmons also showed some good work in galvanometers, resistance coils and a standard ohm.

The general exhibit of Jas. W. Queen & Co. was of great variety and excellence, and the following list contains only a few of the more novel instruments, and those that deserve a special mention.

CAILLETET'S APPARATUS FOR THE LIQUEFACTION OF GASES.

With this apparatus all the gases may be liquefied, and it is so contrived that all the phases of liquefaction and the curious physical

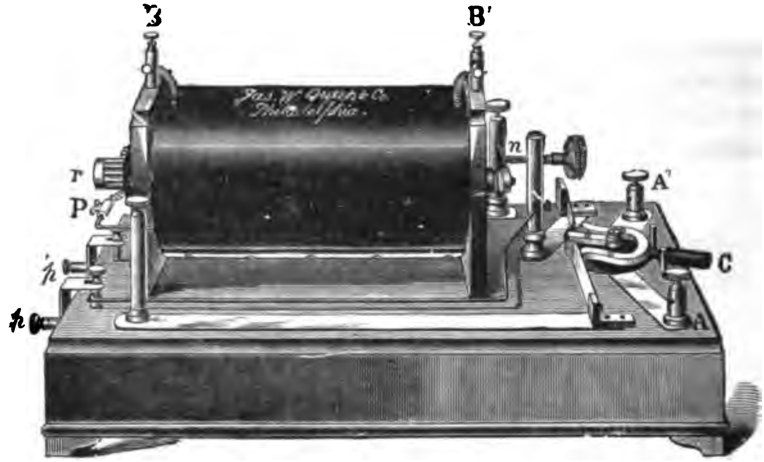


Cailletet's Apparatus for the Liquefaction of Gases.

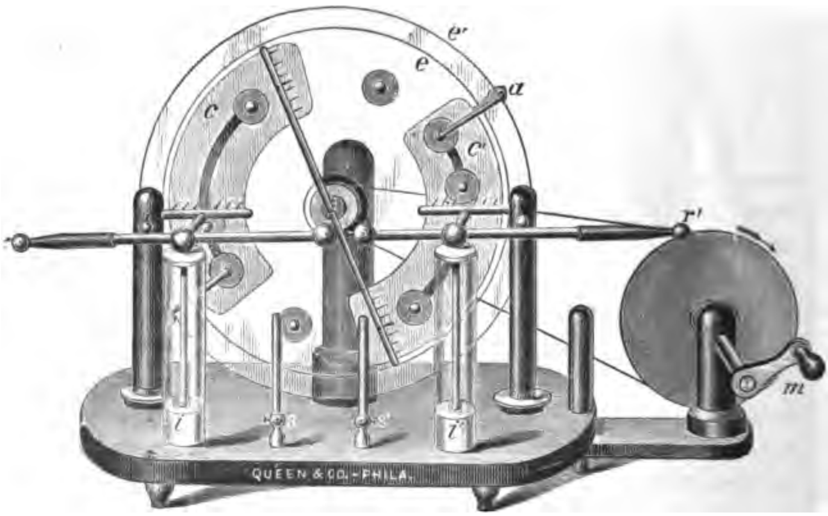
changes that take place at the critical point, may be watched without danger. With the pump a pressure of upwards of 300 atmospheres may be produced, and the gauge gives its indications in atmospheres.

RUHMKORFF COILS.

There were ten different sizes of these instruments shown, varying in length of spark from the one-eighth of an inch to six

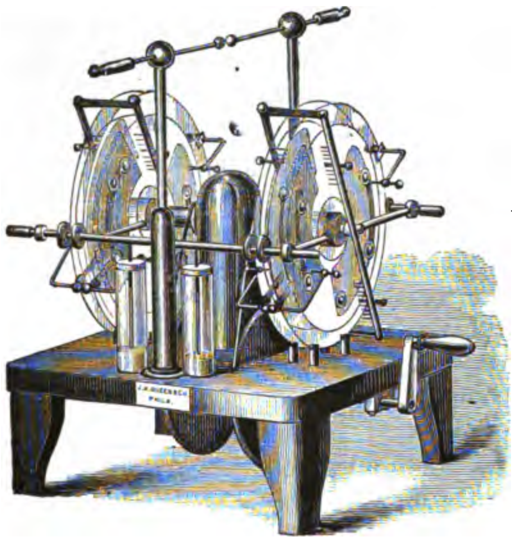


Dissected Ruhmkorff Coil, Bertin Commutator.



Toepler-Holtz Electrical Machine.

inches. Two of the larger of these were of special educational value on account of their structure, as they could easily be dissected. Such a form is more valuable than the one commonly sold for purposes of demonstration. The cut represents one of these, which is provided with the Bertin commutator *C*, which enables the operator to be certain of the direction of the current.



Queen's 4-Plate Toepler-Holtz Electrical Machine.

TOEPLER–HOLTZ ELECTRICAL MACHINES.

The Ramsden frictional machine was quite displaced by the invention of the Holtz machine, as the latter is much more efficient, and vastly more compact. But these machines required charging with a catskin or rubber disc, and would not always work. The self-charging machine called the Toepler-Holtz, leaves but little to be desired in that kind of a machine. There were exhibited, both foreign and home-made machines—all of them efficient.

One of these had a revolving plate ten and one-half inches in diameter, and would give a five-inch spark, while the larger plates give a longer and denser spark.

The cut shows one of the American forms of the Toepler-Holtz machines by Queen, finely finished in mahogany and nickel plated. It has an attachment for medical application, and its current may be taken either alternate or direct. These machines are also made

with double plates having the same diameter, an arrangement which increases their efficiency. By rotating one of the plates of such a machine, the other may be driven as a motor—a most interesting experiment.

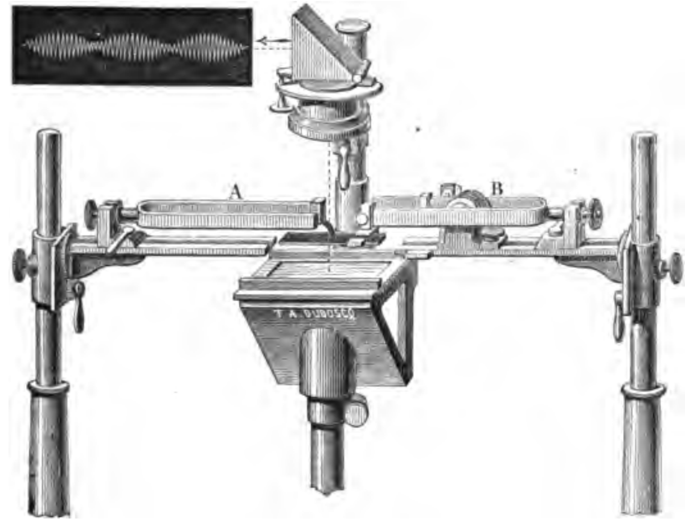
APPARATUS FROM TH. & A. DUBOSCQ, PARIS, EXHIBITED BY JAMES W. QUEEN & CO.

These makers exhibited some very complete optical apparatus for projection on the screen, and for general class and lecture use. Among these was the well known Foucault regulator (see illustration), also a hand electric lamp of a new design, devised by MM. Boudreaux and Th. & A. Duboscq, used at the Polytechnic School of the Sorbonne. They also exhibited a "lanterne photogenique," which is arranged for use with electric light. This is a very fine instrument with two apertures, so that two projections may be thrown on two screens simultaneously.

For use with this was also exhibited a new vertical projection apparatus, perfected by Th. & A. Duboscq, for the projection of two transparent bodies, solid or liquid. This apparatus is furnished with a large condenser of rectangular form, which makes it possible to obtain a very large field, which is an indispensable condition for the inscriptions in the projection of vibratory movements.

There is also in connection with this a very interesting apparatus devised by A. Duboscq, a universal support or electro-diapason, intended to inscribe and show in projection, the vibratory movements. This support on which the diapasons are placed, furnished with stylus and blackened glass, allows of the demonstration in projection of the inscription of intervals; of inscriptions of two vibratory movements, parallel or perpendicular; beats, and the inscription in projection of the optical figures of Lissajous and the experiments of Melde. For the projection of the inscription of sound intervals, with this very interesting apparatus, the two diapasons are placed, one on each support and each furnished with a stylus. The diapasons which have been placed opposite to each others' parallel axes are made to vibrate electrically, the styluses are side by side, and turn in the same way.

There are many other interesting accessories for use with this lantern in connection with electricity: the apparatus of M. Bertin for the electro-magnetic rotation of liquids in hollow magnets, as



Projection of Lissajous's figures by means of Vertical Lantern.

well as the apparatus for the experiments of Arago on the magnetism of rotation. Also a movable arch with support and a series of discs, black and colored, to show the persistance of impressions on the retina, contrast, the admixture of colors, and the complementary colors, with Newton's discs, etc., and the apparatus after Mayer, for showing the experiments of Oersted to demonstrate the lines of currents upon the magnetic needle.

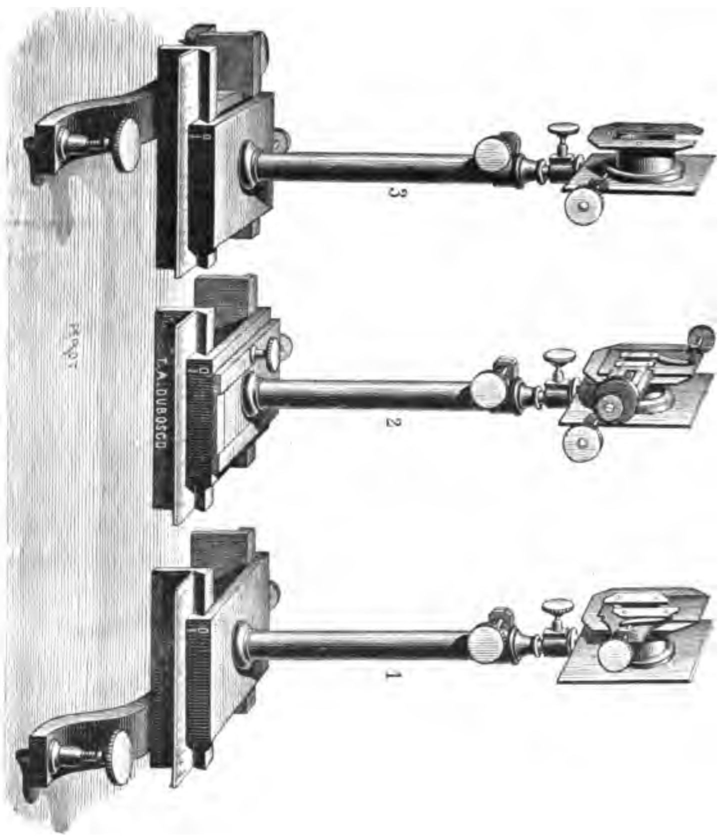
These makers also exhibited a collection of concave and convex lenses upon stands for use with the lantern for projection with electric light; prisms, of solid glass and hollow, containing bi-sulphide of carbon, etc.

Also a new form of Babinet's goniometer, for student's use. A Norremburg apparatus for the study of polarized light, and a very beautiful spectrometer-goniometer, and a collection of photometers of various kinds, Bougeur, Bunsen and Foucault, etc.

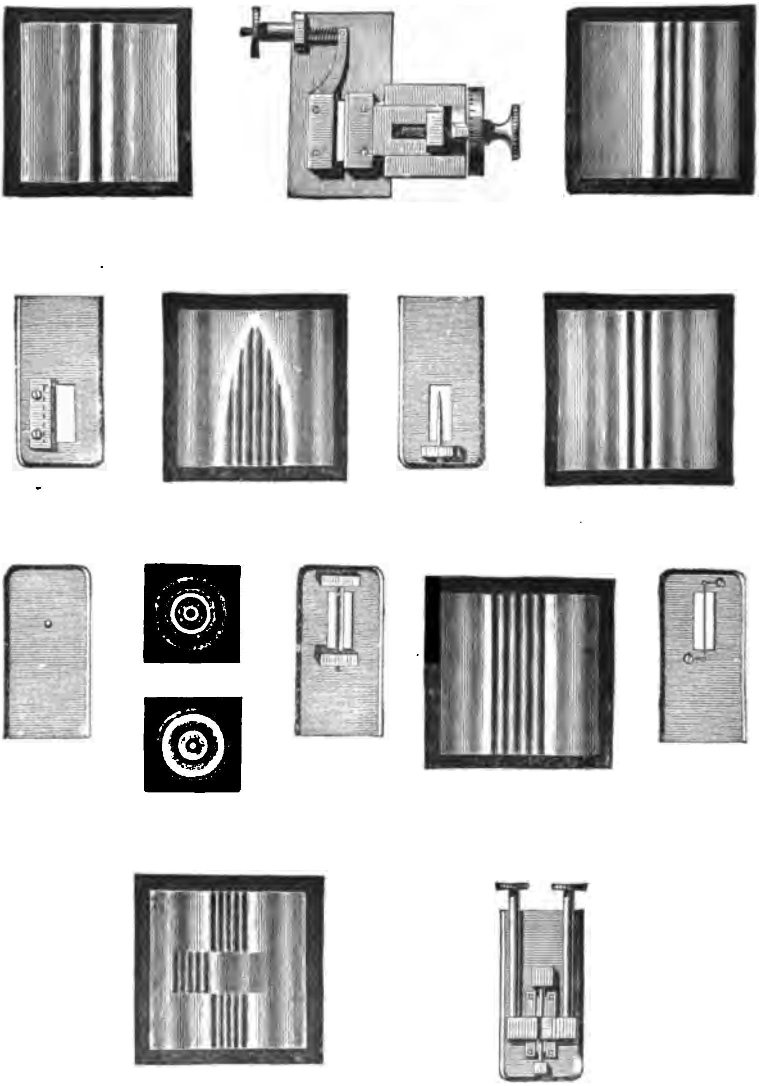
They also exhibited a large diffraction banc. This was a very long and fine one divided into millimetres, and supplied with a very complete set of lenses, slides, prisms, etc., for showing interference, etc., as shown in the figures.

Although few of these instruments are intended for exact measurements, they were of great interest to teachers and lecturers on account of their adaptability for use before an audience, and

Foucault Regulator.

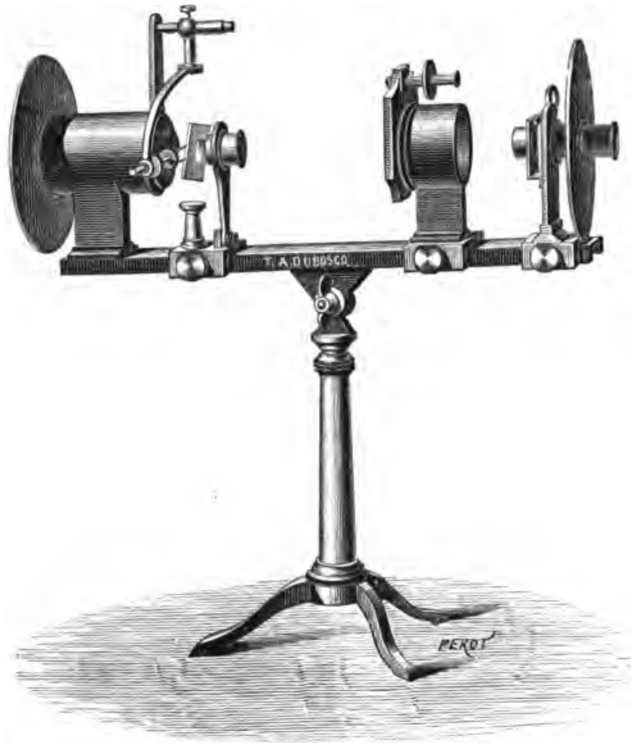


Diffraction Banc,



Interference Phenomena shown by the Diffraction Banc.

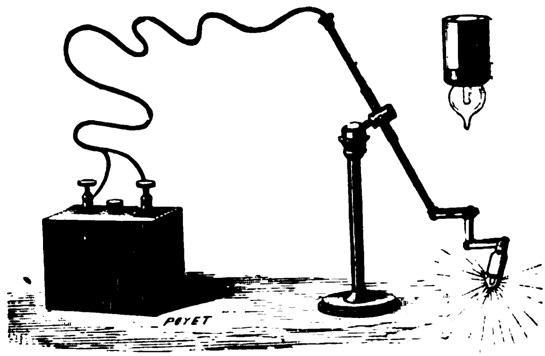
because of the skill which has been used to render them useful for exhibition by means of electric light which is now so much used for scientific work.



Apparatus for the Projection of Circular Polarization in Crystals.

In the collection of Th. and A. Duboscq was also exhibited a very fine apparatus for the projection of all the phenomena of double refraction, rectilinear, circular, elliptic, chromatic and rotary polarization. The apparatus was finely finished in brass, with movable lens and crystal holders, etc., as shown in the figure, with Nicol polarizer and analyser, Delezenne polarizer, glass pile, black glass plates, tourmaline, quartz parallel, quartz perpendicular, one-quarter wave micas, direct-vision prism, compensator and soleil biquartz, rectilinear aperture, microscope, etc., the whole capable of being used with any lantern or *porte lumière*.

L. Aboillard exhibited a fine collection of incandescent lamps



Aboillard's Articulated Electric Lamp Support for Microscopic Use.

from two to 100 volts, various styles of ladies' hair ornaments, butterflies, scarf pins, etc., with miniature lamps mounted in the centre, small pocket accumulators, articulated supports for lamps for microscopic use, etc.

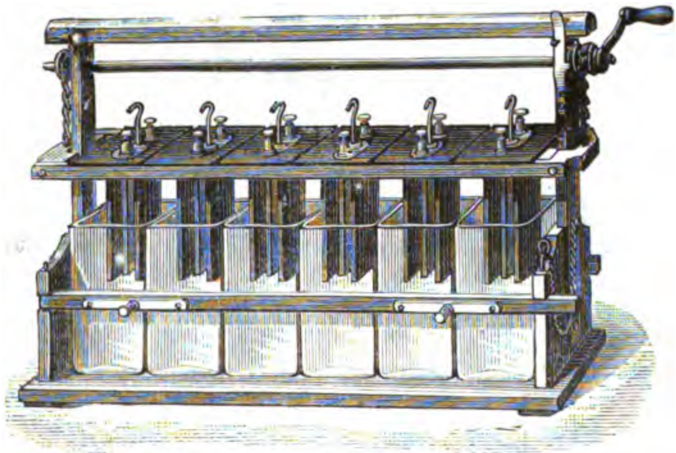
GALVANIC BATTERIES.

Galvanic batteries are yet the simplest and most convenient means for obtaining an electric current for most purposes not requiring great strength or constancy; and the variety of batteries adapted to different purposes is very great. In the report upon batteries will be found some data for judgment as to their adaptation to various uses. But there are many good batteries which were not examined, and among them are such as the Bunsen, the

Grenet Bichromate Cell.

Grenet and the Grove. Of these, the Grenet, or as it is most generally called the bichromate cell, is one of the best. When freshly set up its electro-motive force is just about two volts, and its internal resistance low. Such a one as is represented in the cut, holding out two litres of liquid will rarely measure over a quarter of an ohm.

But it is necessary to lift the zincs out of the solution when not in electrical action, as otherwise chemical action goes on and the zinc is dissolved. When several of these zincs are used together, it is exceedingly convenient to have all the zincs lifted out of their



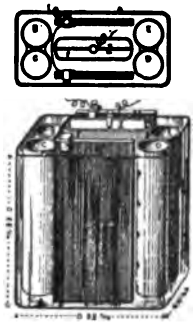
Queen's New Plunger Battery.

solutions at the same time, and Queen & Co. showed a battery of six such cells having a wheel and rachet for lifting out the elements from the liquid when not in use. Such a battery of cells has an electro-motive force of twelve volts, and will yield a current of about ten ampères on short circuit.

Such a battery will suffice for most illustrative and teaching purposes, but if incandescent lighting with it is desired, it will need a ten or eleven volt lamp, which will give four or five candle-power.

What is known as a Chloris Baudet battery or unpolarizable cell, proved upon test to be a first-class battery cell giving an electro-motive force of 1·87 volts, and with low internal resistance and a remarkable degree of constancy when compared with most other cells. This battery is a two-fluid battery, with the zinc in a

solution of an hydrogen-potassium sulphate in an ample porous jar and plates of carbon in the outer jar, which contains a saturated solution of bichromate of potassium and sulphuric acid as is usual in the Grenet cell. If the outer jar be made large enough to permit holding two small porous jars, one to contain strong sulphuric



Chloris Baudet Battery.

acid, and the other crystals of bichromate of potassium, these will diffuse themselves and maintain the strength of the solution. Thus the battery may give a strong constant current for several days.

GEISSLER & CROOKES TUBES.

Queen & Co. exhibited over a hundred varieties of these most interesting and instructive tubes, some of them of great size and beauty. They had provided a darkened room, where they could be seen to advantage in the day-time. These tubes are now so well known that no description of them is needed here, but the committee would remark that aside from the great beauty of some of these Crookes tubes when lighted up by molecular bombardment, the tubes may serve for demonstration in every department of physics. The first laws of motion in mechanics, the development of heat by impact, the development of radiant energy by impact, the production of visible motion and of sound by molecular impact, the electrical phenomena of parallel electrical currents, the effect of magnets upon electrical currents, phosphoresence, fluorescence, etc., etc., so that an ingenious teacher might demonstrate nearly every principle in physics with an appropriate set of Geissler & Crookes tubes. The cuts represent some of the most remarkable of these tubes for the development of motion, incandescence, phosphorescence and the shadow.

Crookes' Tube. Showing the Molecules thrown to a Focus producing Heat in a piece of Platinum Foil.

Crookes' Tube. Containing a Crystal of Iceland Spar.

Ruby Tube. Containing Shells and Minerals of various kinds.

GENERAL PHYSICAL APPARATUS, NOT ELECTRICAL, EXHIBITED BY JAMES W. QUEEN & CO.

A few of these possessing more than ordinary interest, it is thought best to mention here; not with the idea of making a report on them, but because they were exhibited, attracted the attention of many visitors, and were worthy of attention.

A collection of sections of crystals, quartz lenses and prisms and glass crystal models, by Drs. Steeg and Reuter.

One set in a mahogany case contains 178 sections of crystals and preparations. A quartz lens, 75 mm. in diameter and 1,500 mm. radius. Also a cube of uranium, dydimium and sappharine glass and fluor spar, in a case.

A large exhibit of glass crystal models, beautifully made and arranged, showing accurately the axis of the crystals. There were fifty of these models.

Cathetometers of several sizes and forms. One was particularly well adapted to laboratory work, both physical and chemical. It was one and one-quarter metres high, and is so arranged that it may be used either vertically or horizontally. One of these when tested was found to be as accurate and as convenient to use as some costing three or four times as much.

There were models of telescopes, the galilean, the astronomical and the terrestrial, with the direction of the rays indicated by colored threads which are useful helps to beginners in such studies. Also a similar model of a compound microscope.

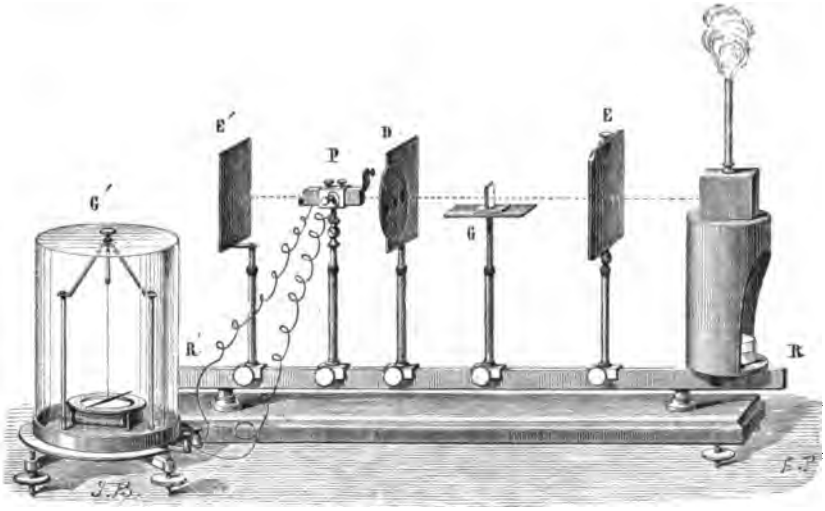
A number of rock salt prisms and lenses, one of the latter being eighty-five mm. in diameter, and thirty collections of gelatine films for selective absorption of colors; the coloring was said to be with chemically pure substances. In each of these sets there were thirty films forming a very convenient and tolerably complete collection.

MELLONI'S APPARATUS.

A finely constructed piece of apparatus for delicate experiments in heat, with between thirty and forty accessories, was shown. It was manufactured by Carpentier, of Paris, and was contained in a very neat and compact case for safe keeping and transportation.

OPTICAL BANC.

There were two of these pieces of optical apparatus with numerous accessories. One of them made of mahogany two metres long



Melloni Apparatus.

and a veneered maple scale graduated to five centimetres. The other one a simple wooden bench one metre long with eight slides, sufficiently good and accurate for most educational purposes.

There was also displayed a fine collection of microscopic apparatus of the finest workmanship, the collection of objects for polariscopic study was very extensive, and many of the objects themselves very beautiful and deserving of mention.

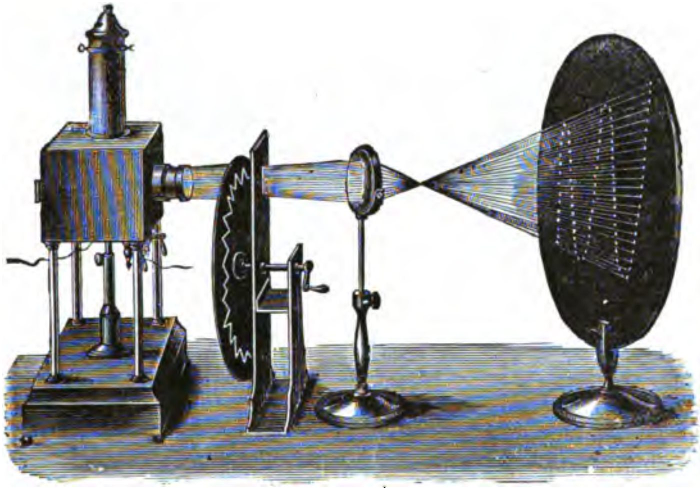
APPARATUS FOR PROJECTION.

A lantern adapted for the projection of all sorts of physical phenomena, as well as the simple projection of transparent photographs was shown. The rivalry among different makers of such pieces has served to develop during the past ten years this very useful adjunct to an educational institution, until almost any phenomenon may be shown upon the screen; and what is really needed is a lantern which can be easily and quickly changed and adapted to different classes of work. Considerable experience has led to the conclusion that such a lantern as was exhibited by Queen & Co. is adapted to as great a variety of work and is manipulated as easily as any one with which the committee is acquainted.

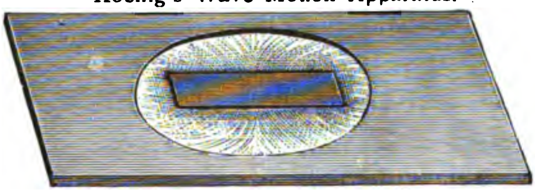
The application of minute incandescent lamps for the illumination of the microscope, has recently attracted considerable

Projector, with Vertical Attachment for Chemical and Physical Experiments.

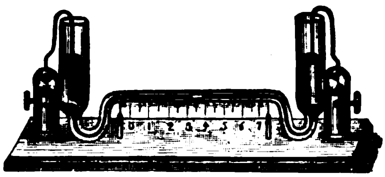
Galvanometers for Projection.



Koenig's Wave Motion Apparatus.

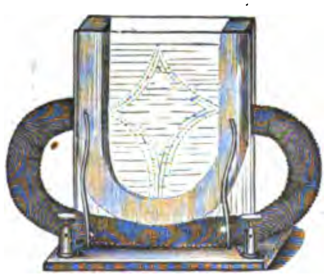


Slide Showing the Lines of Force.

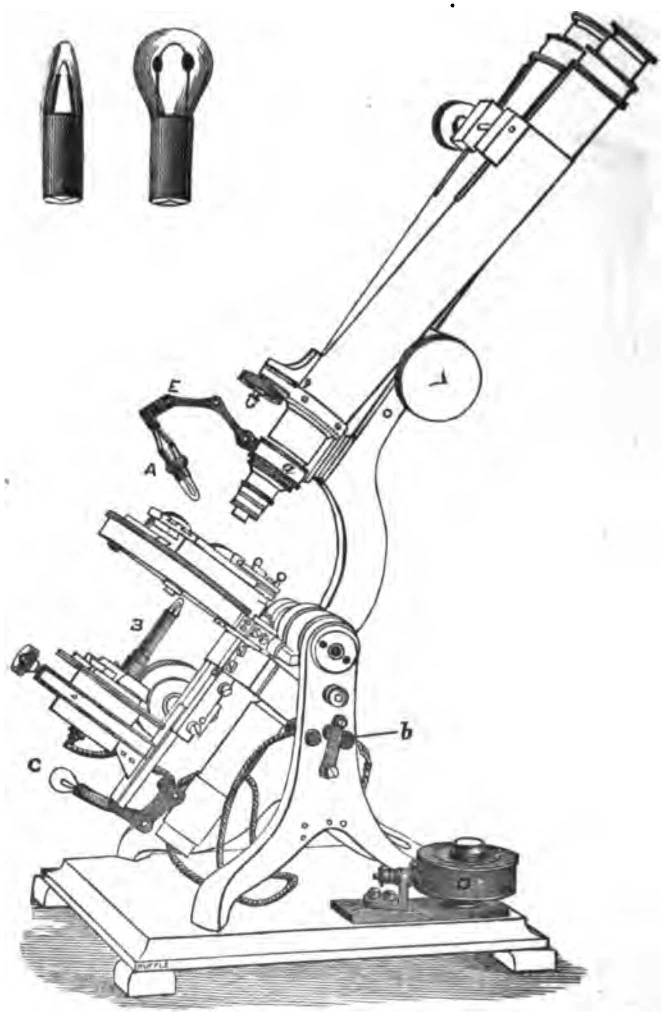


Weinhold's Capillary Galvanoscope.

Voltameter for Projection.



Electro-Magnet for showing lines of Force by means of Iron Filings in a Tank of Glycerine.



Microscope, Illuminated by Incandescent Lamps, showing (for convenience of illustration) several different Forms of Mountings at once.

attention. Messrs. Queen & Co. exhibited five microscopes, binocular and monocular, with various forms of mounting.

One of these is a mounting which fits in the holder of the mirror (the latter being removable) below the sub-stage condenser; another is a separate stand, so arranged with universal movements, that opaque and transparent objects may be lighted with equal

ease. A modification of the latter form fits into the stage forceps hole in the stage.

A form sometimes preferred is where the lamp is mounted to fit in the sub-stage, immediately below the object.

A resistance coil, specially arranged for use with these lamps, was also exhibited. The current is obtained from bichromate batteries, and secondary batteries are also admirably adapted where they can conveniently be charged. A small dynamo machine has very recently been applied to light the lamps direct.

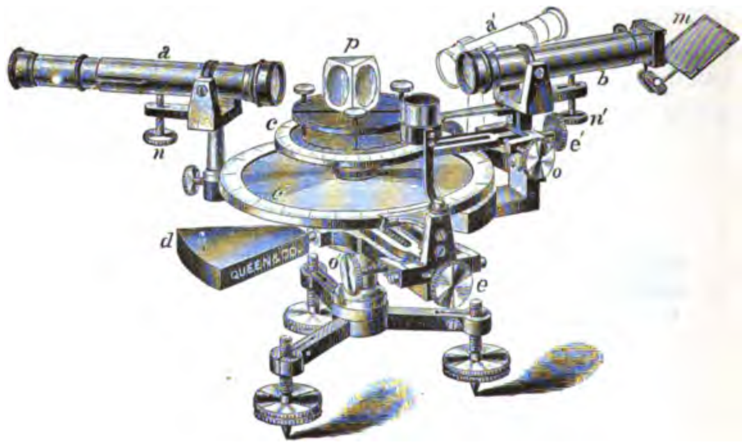
Queen & Co. also exhibited a new spectroscope and goniometer combined. This instrument was specially worthy of attention on account of its excellence of design and workmanship, and reason-

Queen's new Laboratory Spectroscope.

able price. It is supplied with two graduated circles of silver, respectively ninety-five and 105 mm. in diameter. It has a micrometer and vernier, each reading to five minutes. The telescopes are properly balanced to give ease of motion and prevent wear, and are provided with both vertical and horizontal adjustments, while an extra arm permits the telescope to be reversed for use with a grating. The prism stage rotates independent of the circles below, and can be adjusted by means of levelling screws to any

position desirable for either grating or prism. A small heliostat on an universal joint is attached to the slit, thus avoiding the necessity of an extra mirror.

They also exhibited a new laboratory spectroscope for teacher's and student's use, furnished with a flint glass prism *p*, thirty-three mm. high, improved slit, with micrometer screw *n*, adjustable telescope *l*, by means of clamping screw *a*, the telescope has 7 mm. aperature, 147 mm. focus. The prism and telescopes are



Queen's Spectrometer for Laboratory.

mounted on a finely finished brass table, supported on a neat tripod stand, the table is adjusted vertically, and can be fixed by a set screw at the side, complete with comparison prism and photographed scale for measurement of spectra. This spectroscope supplies a long-felt want, and will be of great service for student's use to save larger and finer instruments in the laboratories of universities.

EDUCATIONAL EXHIBIT OF DR. A. E. FOOTE.

This exhibit consisted of a collection of crystals and massive specimens of minerals. The specimens were of the finest sort, and many of them unique. There were collections suitable for instruction in mineralogy and geology, with huge specimens of crystalline masses of quartz, agates, flour spar, amazon stone, beryl, etc.

Henry Whitall exhibited his well known heliotellus and planisphere both efficient as astronomical illustrations, and much used during the past fifteen or twenty years.

Respectfully submitted, A. E. DOLBEAR,
Chairman Section XXIX.

SECTION XIII. APPARATUS FOR HIGH ELECTRO-MOTIVE FORCE. CLASS 2. ELECTRO-STATIC INDUCTION MACHINES, INDUCTION COILS, ETC.

The Committee of the Board of Examiners, to whom was deputed the duty of noting the exhibits in the above class, beg leave to report as follows:

None of the exhibits in this class were entered for competitive examination, they were mainly educational instruments, contained in the exhibit of Messrs. James W. Queen & Co., philosophical instrument makers, of Philadelphia. The committee has thought it advisable, however, to mention briefly some interesting novelties which were found in other exhibits, and which have not yet received public notice

Commencing with the exhibit of Messrs. Queen & Co., the following apparatus may be noted.

(A.) TOEPLER–HOLTZ MACHINES.

There were quite a number of these instruments of different sizes, having one, two and four plates each, the revolving plates varying in size from twenty-six centimetres to ninety centimetres, and having simple self-charging appliances. These instruments worked satisfactorily, yielding a torrent of electric flashes with an expenditure of very little labor. They were conspicuous for their fine finish, nice adjustment, and perfect workmanship. Their immense superiority over the old frictional electrical machines, or the earlier forms of the Holtz machine, has caused them to supplant these entirely. It may be said that they mark an era of progress in the improvement of electro-static induction machines as remarkable in this field of research as has been achieved by the dynamo-electric machine in its sphere.

While the electro-static induction machine cannot compare with the induction coil in its perfect reliability of action in all weather and under all conditions, the improvements noted in its construction have materially enlarged its usefulness in various directions.

(B.) INDUCTION COILS.

A number of coils, both of Messrs. Queen & Co.'s manufacture and imported from M. Ruhmkorff, were shown, varying from miniature size, giving sparks of thirty millimetres, up to instruments giving sparks thirty centimetres long. Some of these machines were provided with the Deprez automatic break, and others with the Foucault interrupter. Some were wound in sections and others were so constructed that they might be taken apart without injury, and the connections exposed to view for purposes of study.

All of these instruments were finished in the best manner, and exhibited a thoroughness of workmanship as well as ingenuity of arrangement, which is highly creditable to the manufacturers.

(C.) GEISSLER TUBES.

These are glass tubes of more or less intricate construction, (sealed at each end and having terminal wires of platinum) from which the air, or other gas, has been exhausted until the pressure does not exceed half a millimetre of mercury. They are designed to exhibit the well known and beautiful phenomena of electric discharge in rarefied gases. In addition to the ordinary forms of Geissler tubes, there were several novel ones of interest. The fluorescent and phosphorescent tubes exhibited were remarkable for their brilliancy. In addition to the above, there were a number of Plucker's spectrum tubes, containing traces of various gases, elements and compounds, yielding brilliant spectra when illuminated by the discharge from an induction coil or Holtz machine, and examined by means of a spectroscope.

The so-called "end on" spectrum tubes are especially valuable in spectroscopic research; from their construction it is possible to obtain the full value of the illumination through the *whole length of the tube* instead of transversely, thus giving vastly more light than the ordinary spectrum tubes, and yielding more brilliant lines.

(D.) CROOKES' TUBES.

It is probable that nothing in the exhibition excited more interest than the exhibit of the magnificent tubes designed by Professor Crookes, to illustrate the properties of so-called "radiant matter." Many of these tubes were four times the size of those used by Professor Crookes in his remarkable address before the British Association, in 1878.

They differ from ordinary Geissler tubes in the more complete exhaustion of the air (not over $\frac{1}{1,000,000}$ of an atmosphere remaining) and from the fact that the ordinary effects of Geissler tubes are absent, while a whole new series of remarkable phenomena appear. It is upon the evidence afforded by the peculiar behavior of the radiant matter in these tubes, when under electrical excitement, that Professor Crookes rests his claim to have revealed matter in a state as far removed from gas as gas is from liquid, or liquid from solid, and he called this supposed new condition the "Fourth State of Matter."

The exhibit comprised all of the forms of apparatus first used by Professor Crookes, as well as some tubes of quite recent device. Messrs. Queen & Co. fitted up a small apartment where these tubes were exhibited to a few people each evening. This firm deserves creditable mention for its enterprise in procuring so large and valuable an exhibit of fine apparatus of foreign and domestic manufacture.

The remarkable discoveries of Professor Crookes have been so fully described in the scientific journals that a detailed notice has not been deemed necessary in this report.

EDISON'S TRI-POLAR INCANDESCENT LAMP.

Apropos to this description of Professor Crookes' radiant matter apparatus may be mentioned briefly a very curious and interesting incandescent lamp in the private exhibit of Mr. Edison, showing phenomena apparently analogous to those of Professor Crookes' radiant matter tubes.

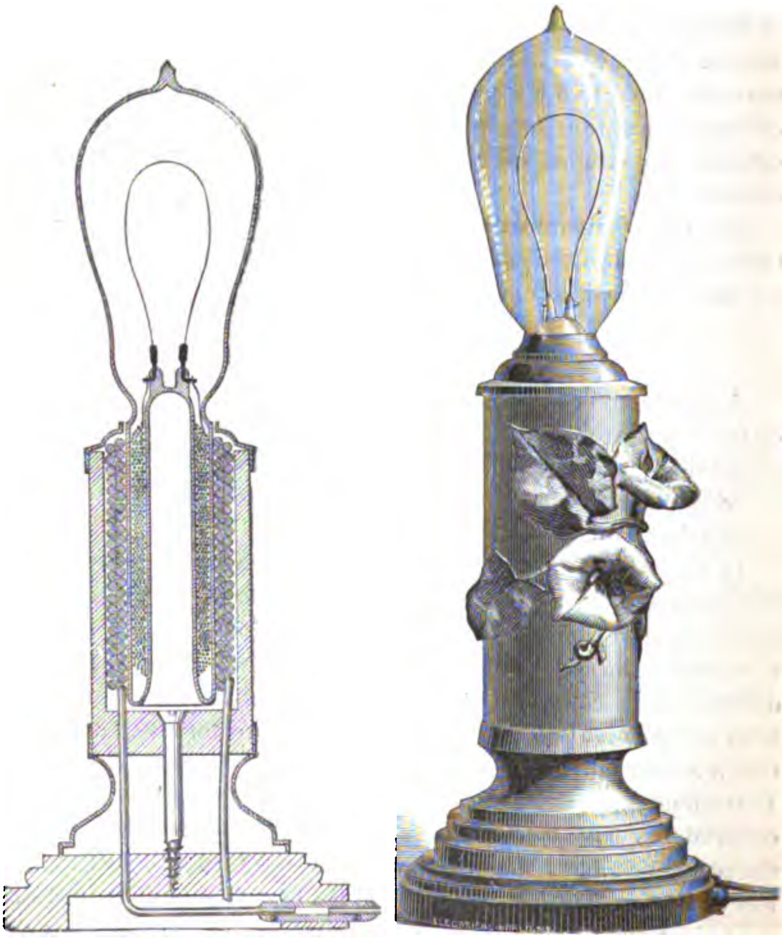
In this lamp a third terminal is inserted, to which is attached a thin strip of platinum foil, which projects upwards to within about two centimetres of the centre of the carbon loop. When the loop is rendered incandescent by an electric current from a dynamo-machine and a connection is made (with a galvanometer in circuit) from the positive pole of the lamp to this third terminal, it is found that a strong current of electricity flows through the galvanometer. This anomalous action has been variously explained, but several experiments have been made with this lamp which indicate that the phenomenon is similar to that discovered by Professor Crookes. For example, it is found that when the platinum pole is enclosed in a glass tube sealed into the bulb in such a position that the

platinum foil is in a direct line with the carbon, the phenomenon appears as before, but when the tube is bent at right angles, no such effect takes place.

Several other interesting experiments with this lamp were described, but not shown, and the effects observed are worthy of more careful study than the committee was able to give at the time.

DIEHL'S ELECTRIC–INDUCTION INCANDESCENT LAMP.

In the exhibit of the Singer Sewing Machine Company, the committee found several ingenious forms of incandescent lamps in



Diehl's Electric Induction Incandescent Lamps.

which no terminal wires penetrate the glass, the whole action depending upon induction through the glass.

These lamps were devised by Mr. Philip Diehl, of Elizabethport, N. J., and require an intermittent current to develop the inductive action; the current from the dynamo does not enter the lamp, but passes into a coil of wire which surrounds a glass tube, forming the base of the bulb. Inside the tube is a second coil, whose terminals are connected with the carbon filament, and when the intermittent current is passed through the outer coil, a secondary current is induced in the inner coil, which heats up the carbon to the point of incandescence.

The inventor stated that the best form of lamp which he had been able to produce on the induction principle, has an interior or secondary coil of only four layers of No. 30 B. & S. gauge, uncovered copper wire. The first layer is wound directly on the inwardly reaching tube of the glass globe, the other layers are insulated from each other by thin sheets of mica, the wire being wound so that there is no point of contact. Naked copper wire is used in preference to insulated wire coil to facilitate the subsequent evacuation of the bulb, as any form of insulating material tends to retard the perfect exhaustion. In order to increase the inductive action, bundles of iron wire are inserted in the centre of the tube, around which the secondary coil is wound.

The weight of copper wire used for the interior coil is one-third of an ounce.

The exterior coil consists of but two layers of naked copper wire, No. 16 B. & S. gauge. These layers are insulated from each other with asbestos paper, the weight of wire being three and one-half ounces.

The exhibitor claimed that the largest lamp shown would give a light of about forty candles, and stated that he had run five of those lamps with an expenditure of one horse-power, and that he was confident that still better results could be obtained when the true proportions of the coils are found by further experiments.

Another style of incandescent lamp was shown, having interior and exterior condensers, intended to be used with currents of very high electro-motive force, as in the Geissler, or Crookes tubes, except that there are no terminal wires liable to become heated, and so destroy the seal. The condensers form a sort of accumu-

lator, so that when the current of electricity is momentarily interrupted, the steadiness of the light will not be affected.

After some difficulty, owing to the absence of the inventor and the want of a suitable dynamo for this purpose, the committee succeeded in operating two of the lamps, by introducing a circuit breaker, but it was not possible to make any tests, either of the candle-power of the light or the power consumed, but the committee is able to state that the carbon filaments glowed with a steady and fairly brilliant light; and while no opinion is expressed as to the practicability of this form of lamp, it was thought that it possessed sufficient novelty and interest to warrant a brief notice in this report.

If there are any other exhibits which the committee has omitted to mention, it must be attributed to the neglect of the exhibitors to notify the Chairman of the Board of Examiners of the objects which they desired to have reported upon, and to the want, during the earlier part of the Exhibition, of an official catalogue.

All of which is respectfully submitted by

JOHN B. DE MOTTE, *Chairman*,
A. E. OUTERBRIDGE, JR., *Secretary*.
Committee on Section XIII, Class 2.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS

REPORTS OF THE EXAMINERS

—OF—

SECTION XXX.

(*SECTION VII, OF THE CATALOGUE.*)

MACHINERY AND MECHANICAL APPLIANCES

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, APRIL, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE
1885.

EDITING COMMITTEE.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

REPORT OF EXAMINERS.

SECTION XXX.—MACHINERY AND MECHANICAL APPLIANCES.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to transmit herewith the report of the Examiners of Section XXX, on Machinery and Mechanical Appliances.

Respectfully,
M. B. SNYDER,
Chairman Board of Examiners.

PHILADELPHIA, *December*, 1884.

Chairman Board of Examiners, International Electrical Exhibition:

SIR:—The Examiners in Section XXX (on Machinery and Mechanical Appliances), respectfully present the following report.

WASHINGTON JONES (*Ch'n*),
Examiners of Section XXX.

PHILADELPHIA, *December*, 1884.

MACHINERY AND MECHANICAL APPLIANCES.

The undersigned members of Section XXX, of the Board of Examiners, appointed to report on Machinery and Mechanical Appliances, would submit the following:

Since it was quite impossible and perhaps under the circumstances not altogether desirable to attempt any tests of the exhibits referred to this section, the report is based on the evident merits of such as were seen in actual use at the exhibition, while in cases where the advantage of this ground of judgment was wanting, it is clear that little more than passing reference to them could be made.

The Chambers Brothers & Co., of Philadelphia, exhibited a brick-making machine, with electrical counter attachment. Though the only electrical part of this machine is the counter, some other useful features are present deserving notice. The clay is tempered and moved slowly forward by knives revolving in a conical chamber of chilled iron, from which it is forced through a rectangular die by a screw fixed to the end of the same shaft which carries the tempering knives. Passing then through a sand-box the clay bar travels on an endless belt to the cutter, which consists of a set of radial arms on the end of a horizontal shaft, each arm having a wire stretched across its forked extremity, parallel to the shaft. Each wire as it is carried around this shaft cuts a brick from the sand coated bar of clay, the motion of the shaft being so adjusted to that of the clay bar by an ingenious arrangement of cams, that the bricks are formed with true, square ends and of uniform lengths. The practicability of this cutting attachment has been fully shown during the exhibition, the machine having made in that time about a million full sized bricks of tempered clay, with sanded surfaces. The whole number of bricks made was duly recorded by the electrical counting device, which was set up in a distant part of the building.

William Sellers & Co., of Philadelphia, exhibited a planer, lathe and geared drill press, in motion, by a Weston Electric Motor.

The Wicaco Screw and Machine Works, of Philadelphia, exhibited in operation a number of machines for the manufacture of screws and sundry small parts of machinery. These machines were designed and manufactured in their workshops, and embrace the most advanced ideas and appliances for this specialty, which add to the economy and quality

of their products. They are of good design, well built and very complete.

The exhibit of Kelly & Co., Philadelphia, dealers in machine tools and supplies, consisted of a Jones & Lamson lathe and large screw machine for heavy work; an E. E. Garvin index milling machine, drill press and grinders; also one Stiles & Parker punch press. These tools are of the ordinary kind, sold by various makers and appear to be well made and adapted for the purposes intended.

The Taper-Sleeve Pulley Works, of Erie, Pa., exhibited several taper-sleeve wood pulleys, three friction-clutch pulleys, a dead pulley and a wooden pulley in halves. The taper-sleeve wood pulley has an iron hub with conical bore, into which fits a split taper sleeve or bushing bored straight to size of shaft. By a large nut on its smaller end, this sleeve is drawn into the hub and its consequent contraction on the shaft secures the pulley in place.

The wooden friction-clutch pulley, consists of a wooden loose pulley having an annular iron flange secured within its rim, projecting toward the shaft. The outer face of this flange bears against the ends of a heavy iron cross-piece, the two arms of which are bolted together rigidly on the shaft. Each of these arms carries two iron levers, the first, inside, next the pulley, has one end, hinged near the shaft, while the other bears against the inner face of the flange. The second lever, which is on the outside, and connected with the first by a bolt passing through the cross-piece, has its fulcrum at the end of the latter, while it carries on its end next the shaft, a cam, which when turned, draws the inner lever toward the cross-piece by means of the bolt, compressing between them a rubber spring placed on the latter.

The two cams have each a projecting arm lying close along opposite sides of the shaft, and a cone sliding on the shaft by a hand lever, separates these, thus turning the cams enough to cause the flange on the pulley to be gripped as in a vise. The gripping jaws are faced with maple wood, which makes them more durable and effective, and easy to repair. The wooden pulley in halves is built up on a web of narrow sectors of wood with the grain running radially, and is provided with an iron hub in halves secured by four bolts. The web is furnished with dowels, and two pairs of clamps bolted through it, form a substantial locking device near the rim.

The dead pulley—also of wood— is designed to facilitate the starting and shifting of a belt when the loose pulley is on the driving shaft.

On a hanger adjoining the pulley is carried a rope wheel concentric with the shaft and turned by the same rope which moves the belt shifter.

By a partial rotation of this wheel, a cam operates two sliding pieces, so that they bear against the loose pulley and press its rim against that of the fast pulley. The loose pulley is thus temporarily coupled to the shaft by friction, and the belt can now be shifted. By a reverse pull of the rope, which for a little way runs freely through the belt shifter, the rope wheel is again turned, removing the pressure and releasing the loose pulley from its hold, and by a still further pull the belt is shifted back again.

Alexander Brothers, of Philadelphia, Pa., exhibit a number of rolls of belting, ranging from 2 to 40 inches in width. They are all oak tanned, of good quality and of uniform thickness and texture. A 34-inch belt transmitting power from the Buckeye Engine, of the Kensington Works, ran very straight with a good contact on the pulleys.

The several rolls of belting exhibited by Charles A. Schieren & Co., of Philadelphia, Pa., from 2 to 5 inches wide, single and double, are of a dark color, owing to a special dressing used in their manufacture, which is claimed to give the belting great pliability, and to make it water-proof as well. That examined was found very pliable with a firm surface texture. Three double belts, a 30-inch, connecting the Porter-Allen Engine with the shafting, and two 18-inches, connecting the latter with a pair of counter-shafts, ran straight and smooth with good bearing.

An investigation of the exhibit of the Shultz Belting Co., of Philadelphia, Pa., showed a peculiarity in the manner of tanning, by which only the surfaces of the belt are oak-tanned, while the interior is only partly so, thereby retaining the properties of raw-hide to a certain degree. By a subsequent mechanical operatien, the requisite pliability is imparted. The belting examined was very soft and pliable, appearing to possess all the qualities of a good article. Four two-ply belts of this description, 8 inches wide, connected the two "Straight Line" engines with the shafting and showed good running and bearing. Two single belts, respectively 1 inch and $\frac{3}{4}$ inch in width, ran two of the Ball Dynamos and gave good satisfaction.

Messrs. J. H. Billington & Co., of Philadelphia, Pa., had an exhibit of Hoyt & Brothers belting which presented a fine appearance, though none of it was seen in operation.

The Ajax Metal Co., of Philadelphia, Pa., exhibited a metal showing

a close, fine, grain, and apparently well adapted to meet the ends for which it is made. A car-wheel journal-box which claims to have had a run of 70,000 miles, presented a good appearance.

The Phosphor-Bronze Smelting Co., Limited, of Philadelphia, exhibited specimens of several grades of metal intended for widely different purposes, as for instance, gear-wheels, journal-boxes, wire, small fittings of various kinds, and also a sheet metal to meet a variety of requiremnets in making electric machinery.

Riehlé Bros., of Philadelphia, Pa., manufacturers of weighing and testing machines, exhibited several of their machines as follows: A light hand machine for testing samples of wire up to 1,000 pounds. The wire is held vertically and stretched by a screw and hand-wheel below the frame, a horizontal scale beam above, serving to weigh the strain. A heavier power machine, the general appearance of the frame being not unlike that of an ordinary lathe, intended for testing single specimens of wire, etc., ranging from a few inches to several feet in length, up to 10,000 pounds strain, The pull is obtained by a back-geared screw run by belt and pulley, and the test-piece held by suitable jaws, transfers the strain to the shorter vertical arm of a bell-crank lever at the other end of the machine, the longer arm of which, extending horizontally along the whole length of the frame, acts on the scale beam placed above, in the usual way.

The third machine exhibited was much larger than the other two, and is operated by a horizontal hydraulic plunger and cylinder, connected with a power pump and accumulator. It is a multiple machine that is intended for stretching and straightening several very long pieces of wire at one operation. For this purpose it is arranged so that the frame and foundation, carrying the straining-head, can be erected 50 or 100 feet, or any desired distance, from the mechanism for holding the other ends of the wires, and weighing the strain applied. The jaws at both ends are arranged to grip from one to six wires at once, a feature of some value for wire mills where it may be desired to carry on such operations with rapidity.

As no arrangements were made to exhibit the working of these machines, it can only be said that they seemed to be well adapted for the work they were intended to do.

The "M. T. Davidson Steam Pumps" exhibited are known as "Heavy Pressure or Boiler Feed Pumps."

It is to be regretted that these pumps were not subjected to systematic trial that a complete report of their performance and merits might be written. They, however, possess many points of excellence which are apparent without extended trial, and which may be thus enumerated.

Uniform velocity of water piston and delivery, under ordinary conditions of supply or suction. The speed may be controlled to any degree of nicety desirable.

The water end, its valves, passageways and piston are admirably arranged for readiness of access and economical working. The small number of working parts must greatly lessen the frequency of adjustment and repair. Lightness, compactness, stiffness and strength are qualities secured by the absence of complicated gearing, and the advantageous position of the frame uniting the steam and water ends.

It should be added, that these pumps are specially adopted to land service, where their highest economy and efficiency would be realized.

The "Chalmers and Spence Pipe Covering," used on all steam pipes in the exhibition building, gave entire satisfaction when first applied, but soon became so charred by the heat of the steam used—about 331° F.—as to be, in a measure, ineffective.

"Burgess' Patent Portable Mechanical Blow-pipes" fulfill all the requirements of the ordinary blow-pipe, and are applicable to a far wider range of work in brazing, soldering, tests and analyses.

The blast supplied is steady, and completely within the control of the operator. Its use admits of the free manipulation of the flame, and object operated upon. It is handy, compact and durable.

The Metallic Gaskets of the "Common Sense Packing Manufacturing Company," employed generally throughout the exhibition building in making the joints of the numerous steam and water-pipes, gave entire satisfaction.

The metal of which these gaskets are made, would seem to be superior to rubber for steam and water joints, enduring a greater degree of heat without deterioration. They can not be blown out by ordinary pressure, are not effected by contact with water or steam, and posseses sufficient elasticity to withstand ordinary shocks and vibrations.

A variety of these gaskets is specially prepared for flanged joints, which from any cause come together imperfectly, and it is believed will meet a long felt want in steam and water-pipe fitting. The packing proper, of this company, specimens of which were exhibited—and of which a wide range of sizes are manufactured—is designed, mainly for piston rod and valve stem packing, and for such purposes we take pleasure in recommending its use. R. C.

Adopted by the Section:

WASHINGTON JONES, *Chairman.*
C. W. SCRIBNER, *Secretary,*

C. CHABOT, JABEZ H. GILL,
G. MORGAN ELDRIDGE, HUGO BILGRAM.
ROBERT E. CRAWFORD, LUTHER L. CHENEY,
CHARLES E. RONALDSON.

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

ON THE

EFFICIENCY AND DURATION

—OF—

Incandescent Electric Lamps.

Report of a Special Committee, appointed by the President of the Franklin Institute, in conformity with a Resolution of the Board of Managers, passed November 12, 1886.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, SEPTEMBER, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1885

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*.
CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL.

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA.
FOR THE PROMOTION OF MECHANIC ARTS.

To the Board of Managers of the Franklin Institute:

GENTLEMEN:—I herewith transmit the report of the Committee, consisting of J. B. Murdoch, Lieut. U. S. Navy; Louis Duncan, Ph.D., Ensign U. S. Navy; William D. Marks, Whitney Professor of Dynamic Engineering, University of Pennsylvania; George M. Ward, M.D., Photometric Expert of the Trustees of the Philadelphia Gas Works, appointed under authority of the resolution of the Board, adopted November 12, 1884, to conduct examinations and tests of the efficiency and life duration of incandescent lamps.

I believe that the examination has been more thorough and that the report is more complete than anything that has hitherto appeared on the subject; and the INSTITUTE is deeply indebted to the members of the Committee for their faithful, zealous, and intelligent discharge of their protracted duties.

Very respectfully,

W. P. TATHAM,
President.

PHILADELPHIA, JULY 8, 1885.

[RESOLUTION OF THE BOARD OF MANAGERS. NOV. 12, 1884.]

WHEREAS, Through delay and lack of time on the part of many of the Examiners, several of the largest exhibits at the Electrical Exhibition have had either incomplete examination or have had none at all; therefore be it

Resolved, That the President be directed to take such steps, appoint such committees, and incur such expense, not exceeding three thousand dollars, as shall be necessary to complete in a satisfactory manner the examination of exhibits.

Mr. W. P. TATHAM,
President of the Franklin Institute.

SIR:—I have the honor to herewith transmit the report of the Committee on the Duration Test of Incandescent Lamps, conducted under the auspices of the FRANKLIN INSTITUTE.

I am, very respectfully yours,

J. B. MURDOCK.

PHILADELPHIA, July 8, 1885.

DURATION TEST OF INCANDESCENT LAMPS.

The scheme for a duration or life test of incandescent lamps was organized during the Electrical Exhibition by the Executive Committee. It had been recognized that tests of incandescent lamps for the determination of the efficiency alone afforded no data for deciding upon their relative value, the lifetime of the lamp being an important factor in the question of economy. A test which should furnish information on this point would be very valuable. Plans were early made for such a test, but as the time required was such that it could not be conducted by the Photometric Group of the Board of Examiners, it was placed in charge of a special committee, and invitations were extended to the principal incandescent light companies to enter their lamps. Before the necessary arrangements could be completed several of the members of the special committee were compelled by their engagements to leave Philadelphia.

The Board of Managers of the FRANKLIN INSTITUTE thereupon placed the conduct of the tests in the hands of its president, who filled the vacancies existing in the committee, and authorized preparations for conducting the test on a larger scale than was possible during the continuance of the Electrical Exhibition. Three rooms in the exhibition building were set apart for the test.

A code had been prepared, specifying how the test should be conducted. This code was signed in December by Mr. Weston and Mr. Upton, representing the interests of the United States and the Edison companies. The Brush-Swan and the Bernstein companies declined to enter their lamps. The FRANKLIN INSTITUTE entered a lot of Woodhouse & Rawson lamps, obtained from the Van de Poele Company, and also two grades of the Stanley-Thompson lamp, made by the Union Switch and Signal Company, of Pittsburg. The president of the FRANKLIN INSTITUTE subsequently entered, for efficiency measurements, and for such a test of duration as circumstances would permit, a lot of Weston lamps (paper carbon), furnished by Mr. Weston; a lot of Woodhouse & Rawson lamps, received from the Edison Lamp Company, and a lot of White lamps, from the Electrical Supply Company.

In order to secure satisfactory results, and prevent needless discussion, the following code was agreed upon for the conduct of the test:

Proposed Code for Duration Test of Incandescent Lamps to be made by the FRANKLIN INSTITUTE *of the State of Pennsylvania.*

The parties hereto subscribing do agree to accept the services of the Examiners herein named, and to abide by the method adopted for the test, and by the results obtained, without appeal.

NAMES OF EXAMINERS.

Lieut. J. B. MURDOCK, U. S. N.	Ensign L. DUNCAN, U. S. N.
Prof. WM. D. MARKS.	Dr. G. M. WARD.

Each company to enter twenty lamps. The Examiners will select fifty lamps from a supply furnished by the companies, of not less than one hundred lamps. Twenty of these will be used in the preliminary adjustment of the circuit, and then replaced at the beginning of the test by twenty similar ones, until then unused, save for preliminary determinations.

A preliminary test of each lamp under normal conditions will be made before the beginning of the continuous test, and the time used will be credited to each lamp.

This preliminary test will determine the spherical intensity of the illumination and the reduction factor.

The FRANKLIN INSTITUTE shall have the right to enter lamps of different kinds for the test, such lamps to be treated in all respects as though entered by a competing company.

The difference of potential between the mains will be kept at 120 commercial volts. Weston's incandescent automatic regulator will be used, and no other adjustment of the potential of the mains will be attempted, save in the case of wide variation. A volt meter will be kept in circuit all the time.

A resistance of German-silver wire will be placed in circuit with each lamp, and a preliminary adjustment made, to give the lamp its proper difference of potential.

Exhibitors will give the potential required by their lamps. Unless the lamps are separately marked, all lamps of the exhibitor will be considered as exactly similar.

An Edison "T" dynamo, driven by a Porter-Allen engine, will be used. The circuit will be opened occasionally and the lamps allowed to cool.

Lamps shall be considered as out of the test when they fail to burn, whether due to breaking of glass or filament. When a lamp gives out, it will be replaced by one requiring subtantially the same difference of potential. The first three lamps of each company which are broken shall be replaced by others for which the preliminary measurements have been made, to be used only in case of accidental breakage.

The test may be declared ended at any time when in the opinion of the committee one system is so far in advance that a longer test could not change the result.

MEASUREMENTS.

Measurements of currents, difference of potential between terminals of lamp, and photometric intensity, will be made. The lamps will be arranged in a circle, having the photometer bar for a radius, and will be placed with the plane of the loop perpendicular to the bar. All measurements will be reduced to mean spherical intensity, by multiplying the intensity measured, by a reduction factor determined for each lamp. Photometric measurements will be made as necessary, but not oftener than once daily.

Electric measurements will be made daily.

A record will be kept of each lamp, in which all data relating to it will be entered.

Weekly reports will be made to the FRANKLIN INSTITUTE of the observations made, and showing how long each lamp has been under test.

METHODS.

The legal ohm will be considered the standard of resistance. The ampère will be determined by the silver voltameter, and checked by calculation of the constant of the current galvanometer used. The volt will be taken as that E. M. F. which produces a current of one ampère in a resistance of one legal ohm. The ampère equivalent of silver as determined by Lord Rayleigh will be accepted as correct.

Currents will be measured by a tangent galvanometer, the constant of which will be determined by the silver voltameter, and checked by calculation.

A standard resistance of German-silver wire wound on a reel will be carefully measured in turpentine or neutral oil, the temperature being observed. The potential galvanometer may be calibrated by connecting to the terminals of this resistance while a current simultaneously measured is passing through it. The temperature of the liquid will be observed and the resistance corrected therefor.

Calibrations will be made frequently during the test.

Potential may be measured by a mirror galvanometer in a shunt circuit of high resistance.

Each company will be permitted to have one authorized representative in attendance throughout the test, and every facility will be given to those representatives to inspect the working of the test that will not interfere with its progress.

The FRANKLIN INSTITUTE agrees to keep the lamps under proper surveillance, and to take necessary precautions for their safety. Lamps accidentally broken will not be charged against the companies.

The right is reserved to discontinue the test at such times and for such periods as may seem advisable or necessary.

A preliminary test will be made before the actual test begins, to insure good working.

In case any objection be made, or difference of opinion should arise between the committee and the contestants, the unanimous vote of the committee shall be final.

If, however, there be not a unanimous vote, the minority of the committee shall appoint one referee and the majority another; these two shall appoint a third referee.

The decision of a majority of these referees shall be final.

(Signed) FRANCIS R. UPTON.

United States Electric Lighting Company,
per EDWARD WESTON, *Electrician.*

The test began with the following lamps entered:

20 Weston,	110½	volts.	Tamadine carbon.
20 Edison,	94–100	"	
10 Woodhouse & Rawson,	55	"	
10 Stanley-Thompson,	96	"	
10 " "	44	"	

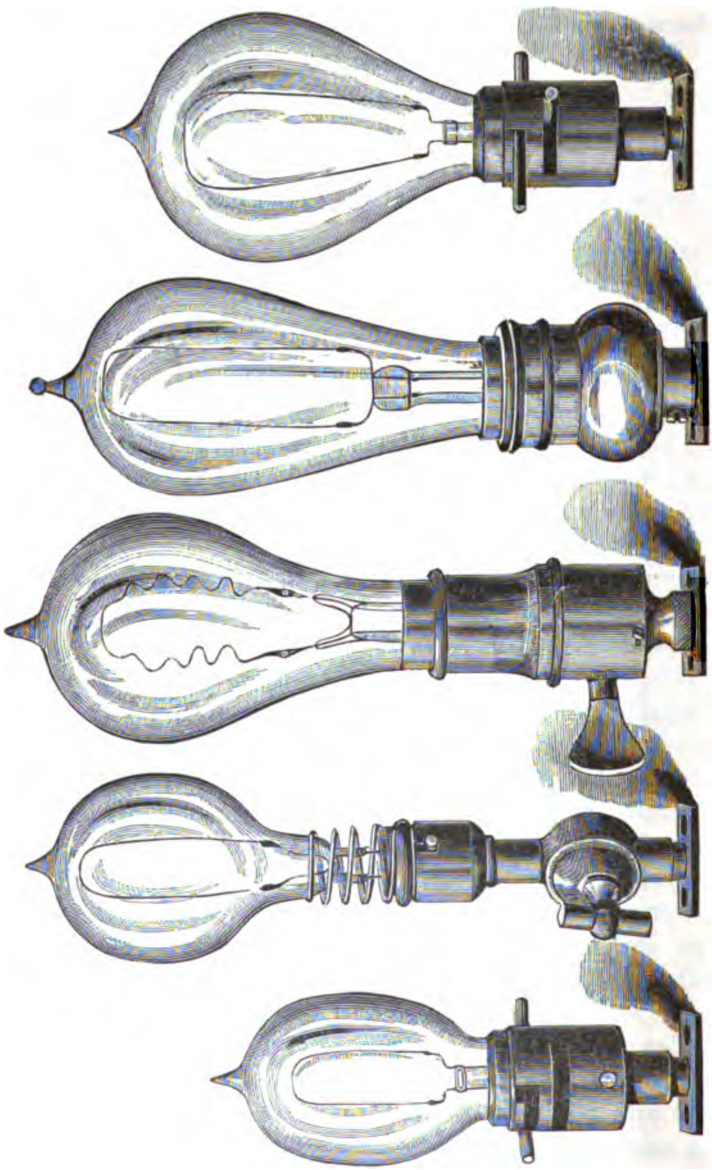
The latter lamps were requested to be entered at sixteen candle power. The committee, after a preliminary trial of several of the lamps, fixed on the potentials of 96 and 44 volts, respectively, for the two grades, as approximately representing that candle power, and the lamps were entered at these potentials.

No official information was furnished the committee as to the process of manufacture of any of the lamps. Their general appearance and the relative size is shown in Fig. 1.

The Weston lamp entered by the United States Electric Lighting Co. has what has been called a "tamadine" carbon. The committee was not furnished with any official information as to the manufacture of the lamp, but the main features were shown by Mr. Weston in his private exhibit at the exhibition, afterwards presented by him to the FRANKLIN INSTITUTE. Gun-cotton in the form of flat sheets was treated chemically to separate the nitryl from the cellulose. The resulting cellulose product is a tough, firm, translucent substance from which the strips are cut in a sinuous form and carbonized. The carbon is rectangular in cross section, but is placed in the lamp so that at the shanks, the longer side of the rectangle is in the line of the shanks, instead of at right angles as in most other lamps. The connections are made at the terminals with minute steel screw bolts and nuts setting up with platinum washers. The bending of the carbon turns the long side of the rectangle so that it lies in different directions at different points.

The lamp is mounted on a wooden base surrounded by a brass ring.

Fig. 1.


Stanley-Thompson.
(44 volt.)
Woodhouse-Rawson.
Weston.
Edison.
Stanley-Thompson.
(98 volt.)

The wires are led down through holes in the wood to the bottom of the base, where one is soldered to a ring and the other is held in place by a small screw, which is concentric with the ring and projecting below its plane. The socket contains two spring clamps against which the terminal ring and screw of the lamp press, the lamp being held in place by a lug on the brass ring fitting into a groove in the socket. The lamps and sockets in the test were readily interchangeable and the connections were good throughout.

The Edison lamps, Fig. 1, were similar in appearance to those generally used. The carbon was made from bamboo fibre. The lamps were mounted in the ordinary screw socket, which gave good contact with great facility of handling.

The Woodhouse and Rawson lamps, Fig. 1, displayed good workmanship and were quite simple in construction. The carbon which is rectangular in cross section is cemented by a very neat joint to two platinum wires, which are kept apart by a glass bridge, and then passing through the base of the lamp have small loops formed in their ends, the loop being made rigid by imbedding the ends in the glass. Two spring hooks in the socket, hook into these loops making contact. The lamps in the test were used with Swan sockets. The loops at the base of the lamp seem liable to injury. Two lamps were disabled by the breaking of these loops before the beginning of the test for duration. No information as to the nature of the carbon was in possession of the committee. Each lamp had the firm name marked on the glass.

The Stanley-Thompson lamps, Fig. 1, had carbons apparently made from thread. No information was given other than that the lamps were made under the Stanley-Thompson patents.

The small, or 44 volt lamp, was well made, so far as the glass work was concerned, the carbon being cemented to platinum wires which were kept apart by a glass bridge and then passed through the base of the lamp. The glass bulb of the lamp was set in a hollow in a wooden base and most insufficiently secured by a cement apparently of plaster of Paris. The wires went through the wood to two small screws. Much difficulty was caused by the cement giving way, so that the wires formed the only attachment of the lamp to its base. The lamp was secured in its socket by two brass bars projecting from the sides of the wooden base, fitting into slots in a brass cylinder socket. Connections were made by two springs at the bottom of the socket pressing against the screws in the base of the lamp. The sockets were not satisfactory,

not being interchangeable readily, and difficulty was constantly met with in shifting the lamps. Several cases occurred of partial carbonization of the wooden base between the wires, causing bad leaks, and in one case it had gone so far as to attract attention by the wood's smoking. The wooden bases were blackened and the leak may have begun over this blackened surface. The difficulties met with in the 44 volt lamp were also encountered in the 96 volt. In addition there seemed to be a point of weakness in the base of the glass bulb, several of the globes breaking at that point after the cement gave way. These accidents occurred in fitting the lamps to their sockets for the test of duration.

All of the above lamps except the Edison bore evidences of the carbons having been "treated" by a deposit from a hydrocarbon gas. The deposit on the Weston carbons was but slight.

After the test for duration had continued about five hundred hours, the FRANKLIN INSTITUTE entered three new lots of lamps as already stated. These were

10 Weston lamps (paper carbon)..	70 volts.
10 Woodhouse-Rawson lamps..	50 "
10 White lamps..	50 "

The Weston lamps were the same in general appearance as the 110½ volt lamps. The carbon, it is understood, is made from paper and subsequently treated to very heavy deposits from a hydrocarbon gas.

The Woodhouse-Rawson lamps were received indirectly from the manufacturers, and were similar in appearance to those already tested, but were more uniform.

The White lamps were somewhat similar to the Woodhouse-Rawson, in external appearance, but the bulb was somewhat longer and narrower. The carbons were cemented to platinum wires, which were separated by a glass bridge, and had loops in their ends for hook connections in a spring socket. No details of the manufacture of these lamps were furnished.

The currents were furnished by an Edison "T" dynamo, worked by a Porter-Allen engine kindly loaned for the test by the Southwark Foundry. Steam was obtained from a locomotive boiler, the property of the FRANKLIN INSTITUTE. The potential was controlled by a Weston automatic regulator, which kept it within about a volt on either side of the normal. Three Edison bridge indicators were in use in differ-

ent parts of the circuit. They agreed in their indications and proved to be very sensitive. A registering telemanometer recorded all variations of steam pressure with great accuracy.

Although the code called for preliminary measurements for the obtaining of the reduction factor only, it was thought best to make electrical measurements as well, that the efficiencies of the lamps might be obtained in watts per spherical candle and comparisons instituted between the different lamps under test.

PHOTOMETRIC MEASUREMENTS.

The measurements of the spherical illuminating power of the lamps were made with the object of obtaining the average candle-power of the lamps, and to avoid the doubt as to the total amount of light which might arise from the various forms of carbon (many of them distorted in manufacture), used by different makers.

Sixty-five measurements or more were made on each lamp. The method pursued may be the more easily understood by a comparison with the parallels and meridians of the earth; referring to points by their latitude and longitude.

The lamp was placed in a vertical position with the plane of the shanks of the carbon at right angles to the photometer bar. The side nearest the bar was marked for future reference. The top and bottom of the lamp were assumed as the north and south poles respectively, and the vertical circle at right angles to the plane of the shanks of the carbon as the prime meridian. The lamp, after adjustment as above, was first rotated horizontally, and thirteen measurements were made in the equator at equal angles of thirty degrees, the last checking on the first. The mean of these measurements gave the "mean horizontal intensity."

Starting again from the first position, the lamp was rotated in the plane of the prime meridian and thirteen measurements were made at equal intervals of thirty degrees, the last checking the first, and making four measurements of the point 0° latitude, 0° longitude. The mean of these four was called the "standard reading." If any noticeable discrepancy was noticed the measurements at this point were repeated. As this point was that on which the calculations for the duration test were based, its careful determination was essential.

The lamp was then moved 45° horizontally, so that 0° latitude, 45° longitude E. was towards the photometer. It was then rotated in the vertical plane passing through that point and thirteen measurements

made as before, at intervals of thirty degrees, the last checking the first.

The lamp was next moved 45° horizontally, so that 0° latitude, and 90° longitude E. was towards the photometer, and thirteen measurements made in that meridian as before.

Lastly, the lamp was rotated till 0° latitude, 135° longitude E. was towards the photometer and twelve, thirty degree measurements made in that meridian, checking with a thirteenth.

This makes a total of sixty-five measurements on each lamp. As the sockets in use with all the lamps prevented the exit of any light from the bottom or south pole of the lamp, the reading at that point was always taken as zero.

The measurements were combined as follows:

The mean of four readings at the north pole of lamp	1
Four measurements on each of the parallels of 60° N. and 60° S. on the prime meridian and 90° meridian circle	8
Eight measurements on each of the parallels of 30° N. and 30° S. at the intersection of the meridian circles of 0°, 45°, 90° and 135°	16
Twelve measurements, 30° apart, on the equator	12
One zero reading for south pole (base of lamp)	1
Making a total of	38

By laying down the points on a sphere it will be found that they are very nearly equidistant, being somewhat nearer at the equator than at the poles.

The average of the illuminating power at these thirty-eight points is taken at the mean spherical intensity of illuminating power.

Fig. 2 shows the location of the thirty-eight points. It is a photograph of a Mueller lamp of nearly spherical shape, around which four rubber bands are stretched to show the four meridian circles, and one rubber band to represent the equator The square black patches show the thirty-eight points.

In order to determine whether the arithmetical mean of these observations gives a close approximation to the mean spherical intensity, calculable from the observations taken, the sphere may be divided into zones, each extending 15° on either side of the equator and the parallels of 30° and 60°, and the spherical intensity be calculated from the area of these zones and the mean candle-power in each. (See Fig. 3.)

The surface of the sphere is developed at the equator by means of a

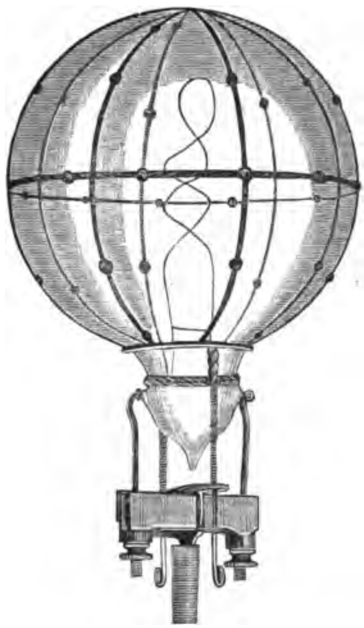


Fig. 2.--Points observed in determination of spherical intensity.

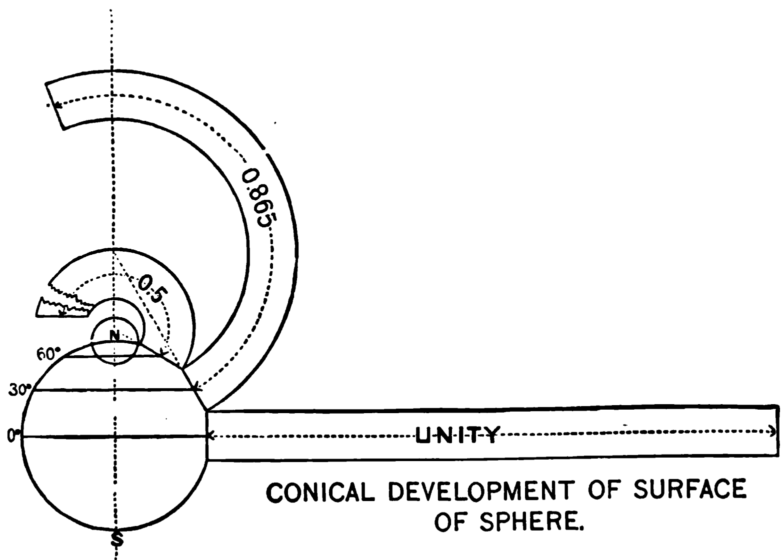


Fig. 3.
(This figure is defective in showing the chords instead of the tangents of the arcs.)

tangent cylinder, at 30° and 60° latitude by means of tangent conical frustra, and at the poles by tangent discs.

If now we multiply the mean intensity of illumination of each zone by its area and divide the sum of these products by the whole area of the sphere, we obtain with very close accuracy the mean spherical intensity of illumination. The following formula gives the method:

$$\frac{\text{Mean eq.} + \text{mean } 60^\circ \text{ lat.} + 1{\cdot}73 \text{ mean } 30^\circ \text{ lat.} + 0{\cdot}131 \text{ poles}}{3{\cdot}861} =$$

mean spherical candle-power.

This method when compared with that in use gives

Stanley (large), No. 26......	13·09 candles.	Method in use.......	13·10 candles.
Edison, No. 2....................	14·30 "	" "	14·38 "

The method adopted yields results giving slight preponderance to the illumination at the equator, but the difference is small, and this method yields itself readily to the mechanical conditions of the lamp-holder.

FIG. 4.—Revolving lamp holder.

From the figure it will be seen that the holder permitted the lamp to be revolved about two axes at right angles in space.

As the lamps to be measured in the preliminary efficiency test altogether required upwards of 10,000 photometric observations, it was quite important to avoid the adjustment of a graduated scale, and the horizontal and vertical axes were therefore fitted with notched plates with 12 notches each and spring catches.

Fig. 5.—Methven Slit and Burner.

The plate for the vertical axis had two extra notches, one at 45° and one at 135°. These notched discs permitted very rapid and accurate adjustment.

The Methven standard two-candle slit was used in all the photometric measurements.

The Committee are indebted to the courtesy of Mr. Alexander P. Wright, of the United States Electric Light Company, for it and for the fittings for the photometer box.

A certificate accompanied this standard signed by Messrs. Methven & Hartley.

It was deemed wise to verify this standard independently, particularly to discover if any error due to personal equation of observer was present.

Standard English candles, a candle balance and stop watch were used in the comparison.

Ten series of five-minute observations showed an error of one per cent. as the result of 100 observations.

Memorandum of Experiments, Comparing Weston's Methven's Standard with Standard Sugg Candle.

Observed Candles.		Time. Min.	Sec.	Correction Multiplier.	Corrected Candle Power.
(1)	1·722	4	45	1·052	1·81
(2)	1·946	5	...	None.	1·95
(3)	1·853	5	15	0·952	1·76
(4)	2·112	5	18	0·943	1·99
(5)	2·050	5	15	0·952	1·95
(6)	1·974	4	45	1·053	2·08
(7)	2·047	5	10	0·968	1·98
(8)	1·939	4	30	1·111	2·15
(9)	2·057	5	10	0·968	1·99
(10)	2·247	5	10	0·968	2·18
Mean of 100 observations..........		....		....	1·984 candles.

Observers: G. M. Ward, Wm. D. Marks.

March 21, 1885.

Fig. 6 represents the Standard Letheby-Bunsen Photometer with 60-inch bar, used in the efficiency tests.

Two reflectors in the disc box reflected a circular Bunsen spot in paraffined paper.

The disc was always moved toward the electric lamp on the left in

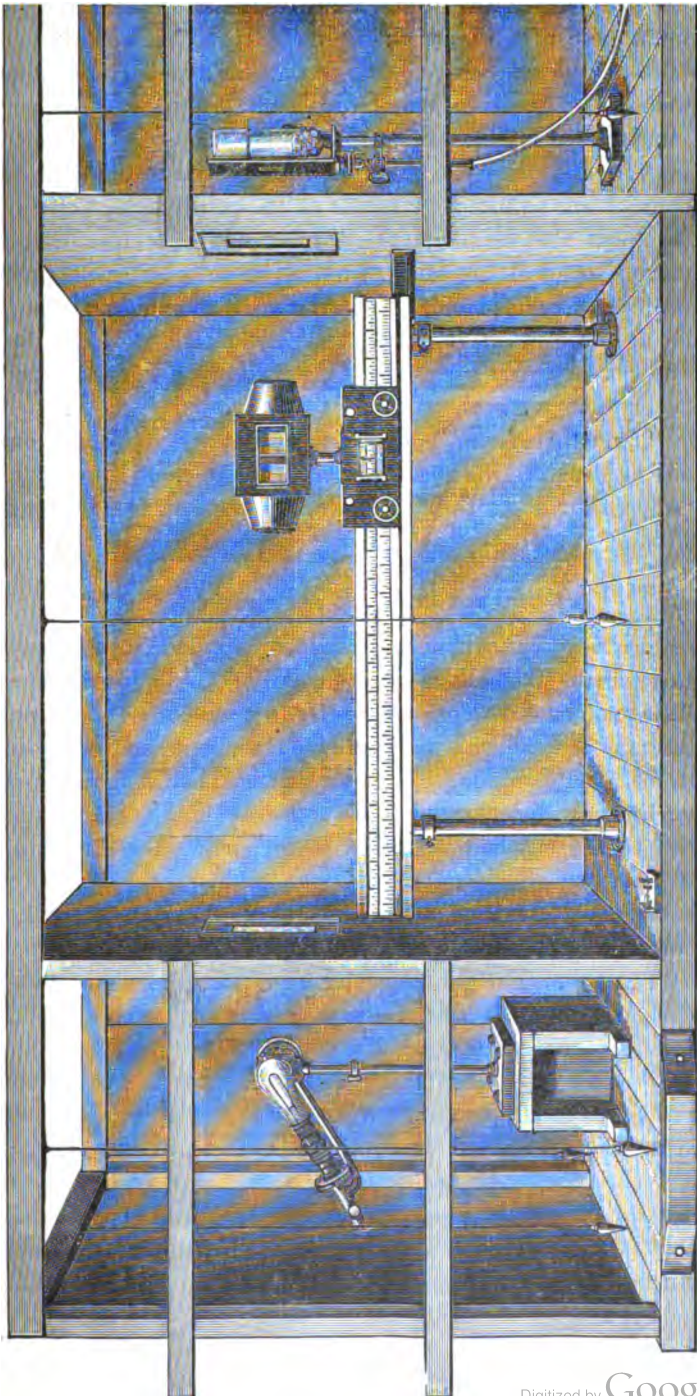


FIG. 6.—Letheby-Bunsen Photometer.

the final balancing of the illumination of the two spots; the wish of the committee being to favor alike the electric lights when in doubt.

It would appear, however, that very near exact justice has been done, since the Methven Standard, which proved to have so little error, was treated in the same manner as the lamps.

The particular lamp to be tested being placed in the lamp-holder, the potential was adjusted by means of the resistances in circuit with the lamp, and the candle power, current and potential determined. The current reached the lamp through wires dipping into mercury cups in the piece of wood at the bottom of the lamp compartment. If a change occurred in the potential, photometric work was stopped until the potential was adjusted. Observations of current were taken about every four minutes.

The "reduction factor" used during the test for duration, was obtained by dividing the mean spherical intensity of illumination by the "standard reading" or the mean of the four observations at 0° lat., 0° long.

ELECTRICAL MEASUREMENTS.

The electrical measurements were made in a small room especially prepared for the purpose. The potential of the lamps was measured by a Wiedemann mirror galvanometer in a circuit of high resistance. The instrument employed was made by Hartmann, and was chosen on account of good damping. It had a Siemens' bell magnet, suspended in a cylindrical cavity in a solid copper block. The mirror was attached to the suspending rod of the magnet. The fibre was about fifteen centimetres in length, and was without appreciable torsion within the deflections used. The deflection of the magnet was observed by a telescope and scale at a distance of 176 centimetres, afterwards increased to 180. The galvanometer resistance was about two ohms, two coils, one on each side of the magnet being used in series, but a resistance of either 50,000 or 100,000 ohms was used in circuit with the instrument, the former being employed with lamps of less than sixty volts potential, the latter with others. The galvanometer was loaned to the committee by Prof. H. D. Todd, of the U. S. Naval Academy, and the reading telescope by Messrs. Jas. W. Queen & Co., of Philadelphia, who (through Mr. Walton, the head of the Philosophical Department) extended to the committee throughout the test, every convenience that their large stock of physical apparatus afforded.

During the preliminary measurements for efficiency the potential was regulated by an observer at the telescope, who watched the deflection and recorded the potential at regular intervals, signaling any change to the photometer room, where the potential was adjusted by a change of resistance in the lamp circuit. In general this method worked well, but occasionally, through irregularity of the engine, the potential would fluctuate. Whenever the working conditions were bad the results were rejected and the measurements repeated.

The lamp currents were measured by a tangent galvanometer specially constructed for the test by Jas. W. Queen & Co. It consisted of a single coil of six turns No. 8 wire, on a brass frame of 60 cm. diameter. The base was of wood, two feet wide, resting on leveling screws. Both galvanometers stood on large wooden posts, buried two and a half feet in the earth, and out of contact with the floors or walls of the building. The needle and compass were loaned for the test by Mr. Weston. The circle was divided to 10′ and could be read by a magnifying glass to 1′ of arc. The maker's adjustments of the needle in the center of the galvanometer coil were carefully verified.

The code prescribed the method by which the electrical units should be reproduced, and was strictly adhered to.

CURRENT.

The ampere was determined both by the silver voltameter and by calculations of the constant. During the test thirty-eight calibrations were made of the tangent galvanometer by the silver voltameter. Eight of these were purely experimental, to determine the best conditions, and several of the others were rejected on account of bad conditions. All those were accepted in which the current was steady, the deposit good, and the time accurately determined. The current was supplied at first by a gravity battery, in multiple series, but later by a secondary battery.

A solution of silver nitrate, one-half saturated, was used in a platinum crucible. The anode consisted of a spiral of silver wire, one centimetre in diameter, closely wrapped in filter paper. The crucible was held in a loop of platinum wire. The time of deposit was either twenty or thirty minutes, depending on the strength of the current. The tangent was read on both sides. The deposit was generally in vertical striæ on the inside of the crucible. Some of the later calibrations were made with a 40 per cent. solution, and this

Table I.

Calibrations of Tangent Galvanometer by Silver Voltameter.

No.	Date.	Time.	Mean deflection.	Deposit Gms.	Change in deflection.	$K = \frac{w}{zt \tan \theta}$	
15	Jan. 23.	20	28° 34′	1·1221	6′	1·5362	Apparently reliable.
16	" 24.	30	31° 35′	1·9042	32′	1·5391	Apparently reliable.
17	" 24.	30	31° 31′	1·8982	28′	1·5382	Apparently reliable.
18	Feb. 8.	30	28° 51′	1·7074	26′	1·5401	Apparently reliable.
19	Mar. 8.	30	31° 47′	1·9239	6′	1·5394	
20	" 6.	30	19° 27′	1·0955	7′	1·5415	Weight uncertain, balance out of adjustment.
21	" 9.	30	48° 29′	2·3439	8′	1·5466	Dynamo current. Apparently reliable.
22	" 9	...	....	....	....	....	Not finished. Silver crystals on anode.
23	" 9.	20	56° 11′	3·0485	6′	1·5452	Dynamo current. Apparently reliable.
24	" 25.	45	17° 09′	1·437	1° 08′	1·5427	Rejected on account of unsteadiness of current.
25	" 25.	20	15° 21′	·5703	1° 29′	1·5486	Rejected on account of unsteadiness of current.
26	" 26.	20	27° 26′	....	3° 00′	....	Rejected on account of unsteadiness of current.
27	" 27.	30	16° 56′	·9399	1° 10′	1·533	Rejected on account of unsteadiness of current.
28	" 27.	20	18° 35′	·6932	46′	1·537	Rejected on account of unsteadiness of current.
29	" 27.	20	22° 21′	·8507	1° 14′	1·542	Rejected on account of unsteadiness of current.
30	" 28.	20	21° 38′	·8205	1° 19′	1·542	Rejected on account of unsteadiness of current.
31	" 31.	20	19° 26′	·7273	11′	1·5366	Apparently reliable.
32	April 1.	20	28° 31′	1·1209	6′	1·5372	Apparently reliable.
33	" 6.	20	38° 32′	1·648	30′	1·5420	Apparently reliable.
34	" 6.	15	49° 41′	1·8341	12′	1·5468	Apparently reliable.
35	" 7.	...	....	....	....	....	Short circuit rejected.
36	May 1.	20	36° 18′	1·5215	5′	1·5434	Apparently reliable.
37	" 20.	20	36° 55′	1·5585	10′	1·5437	Uncertainty in time, due to rate of watch. Time corrected as well as possible. Rejected.
38	" 22.	20	35° 02′	1·4639	4′	1·5452	Uncertainty in time, due to rate of watch. Time corrected as well as possible. Rejected.
39	" 23.	20	35° 01′	1·4515	18′	1·5442	Apparently reliable.
40	" 25.	20	28° 09′	1·1105	21′	1·5464	Apparently reliable.
41	" 27.	20	37° 46′	1·6035	6′	1·5423	Apparently reliable.
42	" 27.	20	42° 18′	1·8854	5′	1·5444	Apparently reliable.
43	" 27.	20	42° 25′	1·8941	5′	1·5452	Apparently reliable.
44	" 27.	17	35° 13′	1·240	8′	1·540	Apparently reliable.

gave a finer grained deposit. After the circuit was opened, the solution was carefully decanted from the crucible, and the deposit repeatedly washed, the washings being tested with sodium chloride. The washing was continued long after a cloudiness was obtained, and the crucible was dried at a gentle heat over a Bunsen burner. The weighings were made on a balance made by Troemner, of Philadelphia, to tenths of milligrammes. The weights used were verified by comparison with a set of standards in possession of Mr. Troemner. Table I shows the calibrations made.

The constant of the galvanometer, K, is derived from the voltameter determination by the formula,

$$K = \frac{W}{zt \tan. \theta}$$

W being the weight of the silver deposit, z Lord Rayleigh's value of the electro-chemical equivalents of silver, taken as ·06708 grammes per minute, t the time in minutes, and θ the mean deflection of the galvanometer.

The error of the galvanometer in reference to the law of tangents was also calculated by the formula given in Kohlrausch's Physical Measurements, and also by Maxwell's formula. Kohlrausch's formula is

$$C = \frac{r\,H}{2\pi n}\left(1 + \tfrac{1}{2}.\frac{a^2}{r^2} - \tfrac{1}{3}.\frac{b^2}{r^2} - \tfrac{3}{4}.\frac{l^2}{r^2}\right)\left(1 + \tfrac{15}{4}.\frac{l^2}{r^2}\sin.^2\theta\right)\tan.\theta$$

in which a =	half breadth of the coil	=	·45 cm.
b =	" depth "	=	·3 "
l =	" length of the magnet	=	1·58 "
r =	mean radius of the coil	=	30·3 "
n =	number of turns in coil	=	6.

The needle was 3·75 cm. in length, but its effective length between poles was assumed as $\frac{85}{100}$ of this. By substituting the above values, the errors can be calculated for different deflections θ.

By substituting the same values in Maxwell's formula, the error of the coil is found to depend mainly on the coefficient G_1, and to be about $\frac{1}{13000}$. The error for the length of needle is shown in the following table:

Deflection.	Error by Kohlrausch's formula.	Error by Maxwell's formula.
10°	− ·0018	
15°	− ·0014	− ·0014
20°	− ·0009	
25°	− ·0002	− ·0002
30°	+ ·0006	
35°	+ ·0015	+ ·0013
40°	+ ·0024	
45°	+ ·0034	+ ·0031
50°	+ ·0044	
55°	+ ·0053	+ ·0054

By Kohlrausch's formula the error is zero at 26° 17′.

The voltameter determinations at different points can be compared by reducing them to 26° 17′ by means of factors derived from the formula. The following results are obtained from a curve of error constructed from Kohlrausch's values given above:

Number.	Deflection.	K.	Correction.	K at 26° 17′.
15	28° 34′	1·536	1·00085	1·536
16	31° 35′	1·539	1·0007	1·538
17	31° 31′	1·538	1·0007	1·537
18	28° 51′	1·540	1·0004	1·539
19	31° 47′	1·539	1·0009	1·538
21	48° 29′	1·547	1·0041	1,541
23	56° 11′	1·545	1·0055	1·537
31	19° 26′	1·537	·999	1·539
32	28° 31′	1·537	1·00085	1·537
33	38° 32′	1·542	1·0022	1·539
34	49° 41′	1·547	1·0044	1·540
36	36° 18′	1·543	1·0017	1·540
39	35° 01′	1·544	1·0015	1·542
40	28° 09′	1·546	1·0008	1·545
41	37° 46′	1·542	1·0021	1·539
42	42° 18	1·544	1·0028	1·540
43	42° 25′	1·545	1·0029	1·541
44	35° 13′	1·540	1·0015	1·538

With two exceptions, calibrations 15 and 40, the values of K fall between 1·537 and 1·542, a range of less than one-third of a per cent. The mean value is 1·5381.

The code provided that the constant of the tangent should also be determined from absolute measurements. The value of H was determined by a Kew magnetometer kindly loaned by Prof. C. F. Brackett, of Princeton. Owing to the presence of iron in the room, the value of H was found to vary materially with changes of position or height. Two complete observations, each consisting of one set of deflections and two of vibration were made with the magnetometer needle in the exact place occupied by the needle of the galvanometer. The value of H from the first set was ·19157 and from the second set ·19137. The mean of the two is ·19147. The value of the constant as calculated from the formula

Constant in amperes $= \dfrac{10\, r H}{2\pi n}$, where $r = 30{\cdot}3$ cm. and $n = 6$, is 1·5389.

The calculated errors were plotted in a curve, together with the actual errors as determined by voltameter determinations, and from the mean a table of values of the constant K was determined, for different points in the circle, and used throughout the test. None of the reliable calibrations, with the exception of No. 40, indicated any change in H or any defect in the galvanometer, and in this case the discrepancy was but slight.

RESISTANCE.

The ohm was by the code to be the Paris or legal ohm. In reproducing it, the committee had access to the standards and apparatus of the Johns Hopkins University, used by Prof. Rowland in his recent determination. The standard resistances of the test and the Wheatstone bridge used had their values carefully determined in Baltimore.

In the reductions the legal ohm was taken as 1·0112 B. A. units.

ELECTROMOTIVE FORCE.

The volt was determined by the fall of potential in a given resistance due to a known current. A reel of No. 22 German silver wire was made by winding the wire on fine glass rods which were let at each end into pieces of black walnut. The turns of the wire were kept apart by turns of silk cord around the posts. The axis of the reel

was surrounded by a stirrer, by which the excessive heating of the wire while in the bath was prevented. This reel was immersed in turpentine and later in refined petroleum (300° fire test, furnished by the courtesy of the Standard Oil Co.), and while in use in calibrations the liquid was kept in motion by the stirrer and the temperature regularly recorded. The ends of the wire were taken to double binding posts at the top of the reel, to which the current and potential leads were connected.

The resistance of the reel was determined, on January 5th, at the Johns Hopkins University, as 21·089 legal ohms at 15·2° C. The reel was then placed in turpentine in the exhibition building, and remained for three weeks before the efficiency measurements began.

It was observed that the turpentine was becoming slightly greenish in color, but no change in the resistance could be detected with certainty by the only bridge at that time in the possession of the committee. As chemical action of some kind was evidently taking place, the reel was removed to a bath of refined petroleum. After the efficiency measurements, the reel was again measured and its resistance was found to have increased to 21·161 at 14° C. In order to determine whether such a change could be due to the chemical action noticed, a gramme of the wire was placed in the turpentine, and in three weeks lost three milligrammes. It was therefore considered by the committee that there was no doubt but that the change of the resistance took place before the efficiency measurements, and the later determination was used in all reductions. After the Wheatstone bridge, loaned by Messrs. Bergmann & Co., of New York, had been calibrated, the resistance of the standard coil was frequently checked. These measurements, extending from —4° C to +19, gave a coefficient of ·0004 for change of resistance per degree Cent.

Calibrations of the potential galvanometer were made by measuring the currents by the tangent galvanometer and simultaneously observing the deflection of the potential galvanometer. The lamp currents passing through the tangent affected the potential galvanometer so that it was necessary to make double readings of the latter with the currents reversed in the tangent.

Each observation with each instrument included two readings on opposite sides of zero, the mean being taken as the true deflection. This method, which was necessary in observations, was adopted for calibrations as well. Calibrations were generally made by the dynamo

currents, in default of a secondary battery. The currents used varied from one to two and a quarter ampéres, giving from twenty-one to about forty-seven volts at the terminals of the standard coil. The calibrations were generally made with the same resistance in circuit of the potential galvanometer that was used in the measurements. The constant of the potential galvanometer was taken as the potential producing a double deflection of one centimetre on the scale. Calibrations were made daily, and in case of any uncertainty were made before and after work. The value of the constant was obtained from formula

$$K = \frac{CR}{D}$$

where C is the current, R is the resistance of the standard coil at the temperature of the observation, and D is the double deflection of the mirror in centimetres of the scale.

It was found impossible to introduce a temperature correction with any degree of accuracy. The room was warmed by a stove, and on account of the low temperature of the building, it was necessary to keep a fire in it constantly. The temperature fluctuations, although not large in amount, were generally very sudden, and anything like uniformity of temperature was unobtainable. The temperature was recorded at first and the attempt made to reduce the values obtained to a standard temperature, but the reductions were found to be of no utility. The temperature of the room ranged between 11° and 23° C. Calibrations were not made at the low temperatures, but the room was heated and kept warm for some time before calibrating. The range of temperature of the coils, while measurements were being made, was probably not more than 7°, involving an extreme possible error, from inability to determine the temperature correction, of $\frac{3}{10}$ per cent.

MEASUREMENTS OF EFFICIENCY.

The general method of making the observations for efficiency has already been stated. The committee aimed to test each lamp at its normal potential as stated by the makers, and to place it in the test for duration at the same potential, that the relation between efficiency and life might be traced. A few lamps were tested at two or more potentials. The efficiency measurements were begun at the earliest moment when it was thought that the arrangements for the test were sufficiently advanced to secure good results.

The constant of the potential galvanometer had been determined from only a few calibrations, and the error of the tangent galvanometer was not known as well as it was later in the test. Owing to the chemical action of the turpentine on the German-silver of the standard coil used in calibrations for potential, the resistance was underestimated and the potential constant determined by calibrations was too small. After the efficiency measurements were all completed, the observations were recalculated, allowing for all known errors as determined by later measurements. The result was to raise the potential in almost every case above what was thought to be its value at the time the observations were made. In the following tables the potential is that at which the efficiency measurements were made as determined by the corrected calculations.

The diagrams show the curves of illumination in five planes passing through the centre of the lamp. The first is a horizontal plane, the equator, the others marked "vertical" are vertical planes, making angles of 45° apart. The black line in each circle shows the plane of the shanks of the carbon; the parallel lines at 0° of each circle represents the position of the photometer bar. The circles are drawn with a radius of sixteen of the scale of candle power. The following points on the different circles are coincident.

0° on horizontal and 0° on vertical 0°.
90° on horizontal and 0° on vertical 90°.
180° on horizontal and 180° on vertical 0°.
270° on horizontal and 180° on vertical 90°.

The four 90° points on the vertical sections represents the light given off at the top of the lamp.

The four 270° points in the vertical sections correspond to the base of the lamp.

The horizontal distribution is found in all the lamps tested to be dependent on the cross section of the carbon. If this is circular as it is in the Stanley and White lamp, the curve of horizontal illumination is practically a circle, if rectangular, as in the Edison and Woodhouse and Rawson, the greatest illumination is given in that direction towards which the longest side of the rectangle is turned.

Lateral twist causing the major axis of a rectangular cross section to lie in different directions at different heights in the lamp, produces a marked effect as is seen by the curve of the Weston lamp. The light given off at the top of the lamp depends in the same way on the

amount of illuminating surface visible from that point. In the Edison lamp, which has a long carbon, the two branches being comparatively close together, but little illuminating surface is visible from the top of the lamp, and but little light given off. In the Weston lamp, however, the carbon is bent into a curve, more closely approximating to a circle, and the lateral twist given the carbon turns the long side of the rectangle in the middle of the loop towards the top. These two causes result in turning a considerable illuminating surface in that direction, and consequently in giving a large proportion of light.

The committee is indebted to Mr. C. H. Small, of the University of Pennsylvania, for the averaging of results and the construction of the light curves.

EDISON LAMPS.

Although only twenty-three lamps were required to be measured for the duration test, a larger number were examined, and the efficiency results are appended. The first twenty of the lamps were tested for duration, and the curves in the diagram, Fig. 7, were calculated from them. But few peculiarities were observed in these lamps. One, through a peculiar distortion of the carbon gave an almost circular curve of horizontal distribution, but the curves of the others were essentially the same as in the diagram. Owing to the causes already mentioned the potential of the lamps is generally $\frac{7}{10}$ of a volt higher than the normal. The tables give all the data of the tests. The lamps were taken at random from four hundred furnished by the company.

STANLEY-THOMPSON LAMPS (96 VOLTS).

Fourteen of the 96 volt lamps were tested for efficiency, four of the original having been broken in fitting them to sockets preparatory to the test for duration, and four others tested in their places. The high potential of lamps 37, 41 and 51 was due to an error of calculation, which, corrected after the efficiency test, gave the high figures recorded. The curves in Fig. 8 are the averages of the first eleven lamps in the table, and the averages in the plate are those of the first ten. The lamps were taken from a lot of fifty.

STANLEY-THOMPSON (44 VOLTS).

These lamps gave the highest average efficiency of any lot under test, but varied considerably from each other. The curves are essentially the same as those of the 96 volt lamps, except in giving less light at the top of the lamp. The lamps were taken at random from a lot of fifty.

WOODHOUSE AND RAWSON LAMPS.

Two lots of these lamps were tested. The results obtained were generally the same. The first lot were marked 55 volts, and were taken from twenty-five lamps furnished. The slight irregularities in the curves (Fig. 10) are due to the fact that the lamp was mounted on a spring socket (Swan) in the efficiency measurements, and the motion and vibration of this socket in moving it through the various positions occupied, prevented as accurate measurements as in other cases, where the lamp was held rigidly.

The second set of Woodhouse and Rawson lamps, selected from fifty furnished, were marked 50 volts, and a paper accompanying them from the makers, invoiced them as "20 candle-power, 50 volt" lamps. They were tested by the committee, as the duration test on the former lot was unsatisfactory by reason of many of the lamps being connected two in series. On setting the new lot up at 50 volts, they were found to give only twelve spherical candles, and to have an efficiency of about five watts per candle. The Woodhouse and Rawson is known as a very economical lamp, and has of late attracted much interest on that account. A duration test of 300 hours was all that could be allotted to these lamps and would determine nothing if the lamps were tested at so low candle power. As the resistance of the lamps cold was the same as some of the first lot of 55 volts, the committee determined to test the second lot at that potential also, with a statement of the facts.

WHITE LAMPS.

These lamps were taken from a lot of twenty-four. The carbon is apparently made of thread, has a circular cross-section, and is heavily treated. The curves of the whole lot are almost identical. The lamps were tested with spring sockets received from the Electrical Supply Co., and to the vibrations and lack of rigidity of this socket during the revolutions of the lamp holder, is attributed the slight want of symmetry observable in the curves in Fig. 11. The cold resistance in the table of the figure is unquestionably an error, but was not discovered until too late for correction. The lamps decreased in resistance during the duration test. The average cold resistance before use, of several lamps of the same lot, was found to be 102 ohms, and those under test probably averaged about the same.

WESTON LAMPS (110½ VOLTS).

In submitting a report on the tests of these lamps, the committee think it proper to give a resumé of correspondence between Mr. Weston and themselves. The 110½ volt lamps were received from the United States Company in January. Efficiency measurements were made on the 5th, 6th and 7th of February. On the 18th of February, Mr. Weston visited the exhibition building, was shown the results of the efficiency measurements on his lamps, examined into the installation, and the working methods of the test, and thinking the candle-power of some of them low, addressed the following to the committee:

PHILADELPHIA, February 18, 1885.

Having examined the methods of testing used and the results obtained in the efficiency determinations, I would request a re-measurement of my lamps numbered 4, 6, 15 and 17.

I am satisfied that the methods used are such as will produce correct results.

EDWARD WESTON.

The lamps designated were re-tested and the accuracy of the former measurements verified. On the 7th of March the preliminary run for working methods began. Owing to irregular working of the engine, causing flickering in the lamps, it was prolonged a week, that better

working might be secured. On March 17th the committee had arranged to begin the duration test at 2 P. M. Very shortly before that time, the representative of the United States Company, who had not been in attendance on the tests for several weeks, although his presence had frequently been solicited, arrived with the following letter from Mr. Weston:

LABORATORY OF EDWARD WESTON, 107 ORANGE STREET,
NEWARK, N. J., March 16, 1885.

PROF. WM. D. MARKS.

DEAR SIR:—The very marked difference in candle-power of our lamps, as shown in the tabulated results of the tests made in Philadelphia, surprised me very much, particularly as our lamps are remarkably uniform in this respect, and must necessarily be so when properly made, owing to the peculiar method of treating the loops.

After arriving here I commenced to investigate the matter, and soon found that you had been supplied with a singularly bad lot of lamps; the defect being due to imperfect baking of the loops. This has been so imperfectly done that you will find it impossible to maintain the candle-power uniform for even a very short period of time without increasing the E. M. F. The resistance of the loops will rise rapidly, and the lamps will rapidly deteriorate and fail in such a short time, as to leave no doubt in your mind that if we made such lamps regularly we could not possibly continue to do business. In other words, the lamps are thoroughly worthless.

In view of these facts I think it is useless to spend any time on the lamps of our make which you now have, and since there is no provision in the code for such a contingency as has arisen, I respectfully submit this statement of facts to the committee, and ask for a careful consideration of the matter.

Deeply regretting that anything should have occurred on our part to still further prolong, and increase the cost of a series of tests which must necessarily be very tedious and expensive, I remain,

Yours, respectfully,

EDWARD WESTON.

The members of the committee present agreed with Mr. Weston that the code provided no remedy for a case of this kind, and agreed to postpone the beginning of the test and to refer the matter to the Edison Company, that the competing parties might enter upon new arrangements. The Edison Company through Mr. Upton agreed that Mr. Weston should have the privilege of entering another lot of lamps of the same general character and grade as those already tested, and the committee desirous of obtaining good lamps for test, agreed to measure them when received. On the 1st of April a conference took place

between Messrs. Weston and Upton, the president of the FRANKLIN INSTITUTE and a portion of the committee, at which Mr. Weston stated he thought there would be no doubt but that the new lot of lamps would be on hand within a week. The allotted time expiring without anything being heard from him, the following letter was sent:

PHILADELPHIA, April 8, 1885.

MR. EDWARD WESTON,
Electrician of the U. S. Electric Light Co.,
Newark, New Jersey.

DEAR SIR:—Since your letter of March 16th, 1885, the committee of the FRANKLIN INSTITUTE appointed to conduct the competitive duration test of electric incandescent lamps have been awaiting the receipt of other lamps to replace those which in your letter you condemned and pronounced worthless. Our letter of the 17th ultimo conveyed to you an expression of our willingness to undertake the additional labor necessary to test a new lot of lamps. Hearing nothing further from you regarding lamps, we telegraphed for date and received no reply, on March 26th. On March 30th, a fortnight later than your letter, we wrote to say that the tests would begin April 3, unless some sufficient reason for delay was assigned. At our verbal conference of April 1st, our understanding was that your new lamps would certainly reach us by to-day. We again telegraphed you yesterday afternoon. The engagements of some of the members of the committee will prevent the completion of the duration test if further postponement occurs. In justice to the FRANKLIN INSTITUTE this test must be completed.

The committee in the absence of any reply relative to our telegram of yesterday, feel compelled to fix Saturday the 11th, current, as the date beyond which further postponement is impossible. This will have given you twenty-five days in which to replace lamps pronounced worthless in your letter of March 16th. The committee have stretched the allowable time of delay to the utmost and regret the imperative necessity which forces them to fix a limit to it.

The committee interprets your letter of the 16th as a withdrawal of your lamps of the 40 grade (110½ volt.)

If new lamps of similar grade are not received by Saturday forenoon, April 11th, the duration test will proceed without your lamps and the United States Electric Light Co. will not be regarded as a competitor. The 70 volt lamp now measured will, however, be tested as a matter of scientific interest, but not in competition with other lamps.

We regret that circumstances force us to make this decision, and will be more than pleased to have you enter as a competitor. Our limited time and means will not permit further delay.

I am, very truly yours,

WM. D. MARKS.

This letter was written with the knowledge of only a portion of the

committee, who assumed that the Edison Company would not compete with lamps pronounced worthless by their maker.

On April 9th another conference was held at which the representative of the Edison Company objected to Mr. Weston withdrawing his lamps, and addressed the following letter to the committee:

Prof. WM. D. MARKS, *Chairman.*

DEAR SIR:—The Edison Company desire that the test of lamps be proceeded with under the code without further delay.

Respectfully,

FRANCIS R. UPTON.

65 Fifth avenue, April 9th, 1885.

This request that the test should be continued under the code, the failure of Mr. Weston to provide new lamps, together with the impossibility of further delay if the test was to take place at all, gave the committee no option, but to proceed under the code with the lamps on hand. In order to prevent any misunderstanding on the part of Mr. Weston, he was notified by letter and telegram that the test would begin on the 11th. A few hours after the beginning of the test, the following telegram was received:

Prof. WM. D. MARKS.

Your telegram surprised me. The lamps have been withdrawn. Our position in this respect is fully caused by your letter of April 8th. I presumed that this was the final judgment of the committee pending a reply from me. There is no clause in the code by which the Edison Company can compel the committee to proceed as indicated in your telegram, neither the committee nor the Edison Company have any right to re-enter our lamps without our consent. My letter in reply to yours of the 8th will fully cover these points.

EDWARD WESTON.

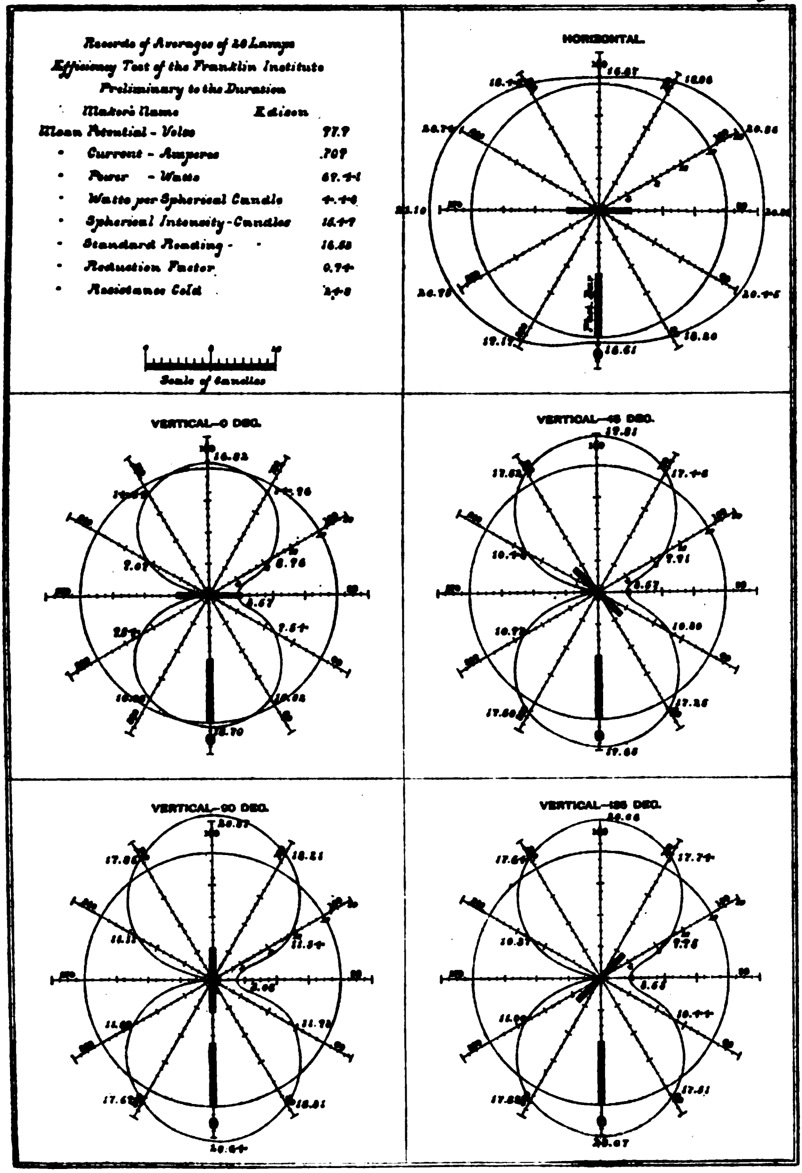
The matter was immediately considered by the full committee and answered as follows:

PHILADELPHIA, April 11, 1885.

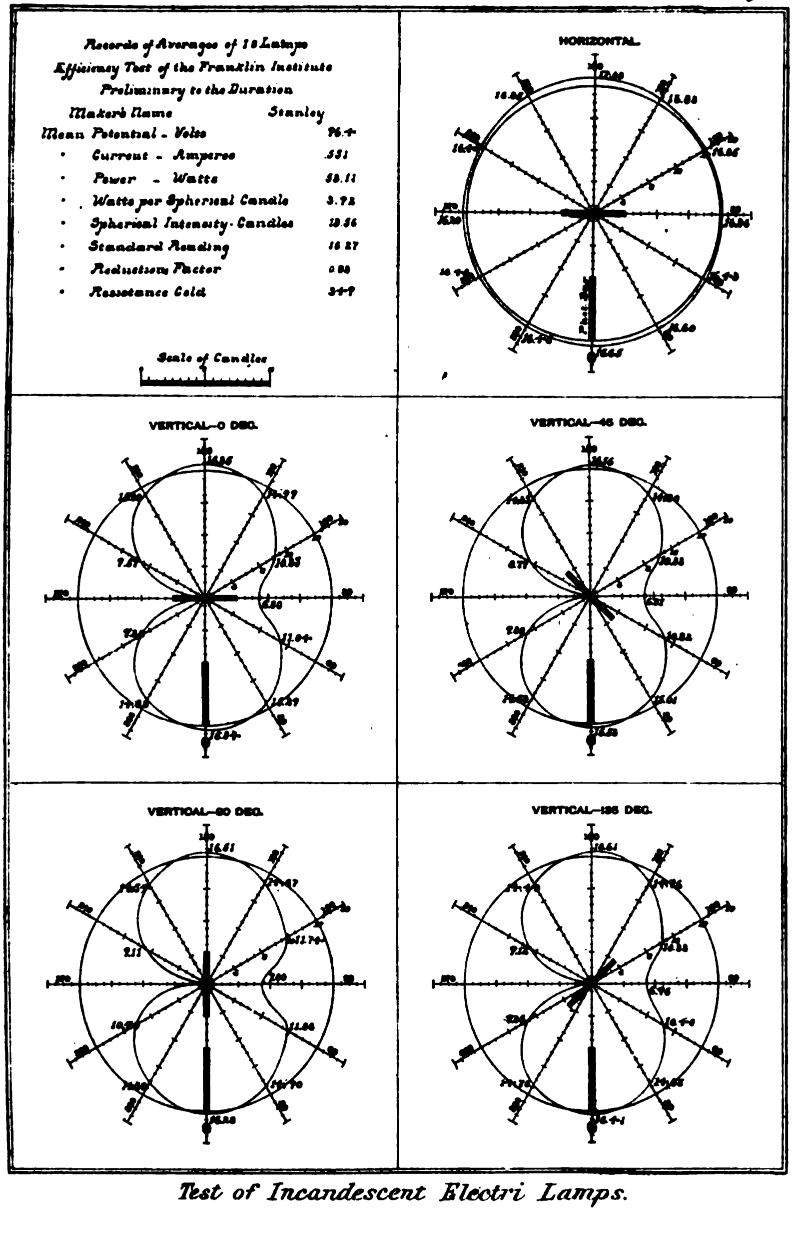
EDWARD WESTON,
Newark, New Jersey.

In reply to your telegram of to-day the committee have considered the question you raise. It was understood by them that the verbal conference of Thursday evening at which you were present, made it clear that the formal demand of one of the competitors that the test should proceed, left the members of the committee then present no option in the matter and rendered the letter of the 8th nugatory. Under the provisions of the code any questions between the contestants and the committee can be settled by a unanimous vote of the committee, and the undersigned give their deci-

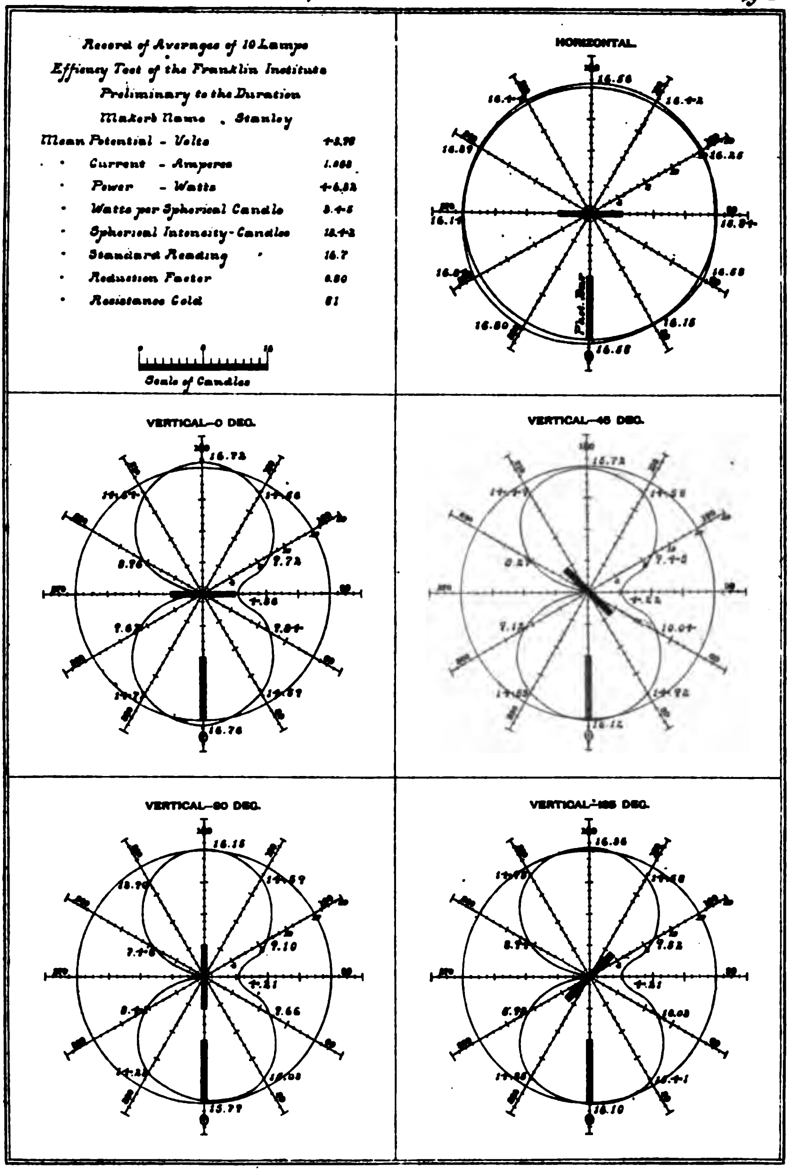
Fig. 1.



Test of Incandescent Electric Lamps.



Test of Incandescent Electri Lamps.



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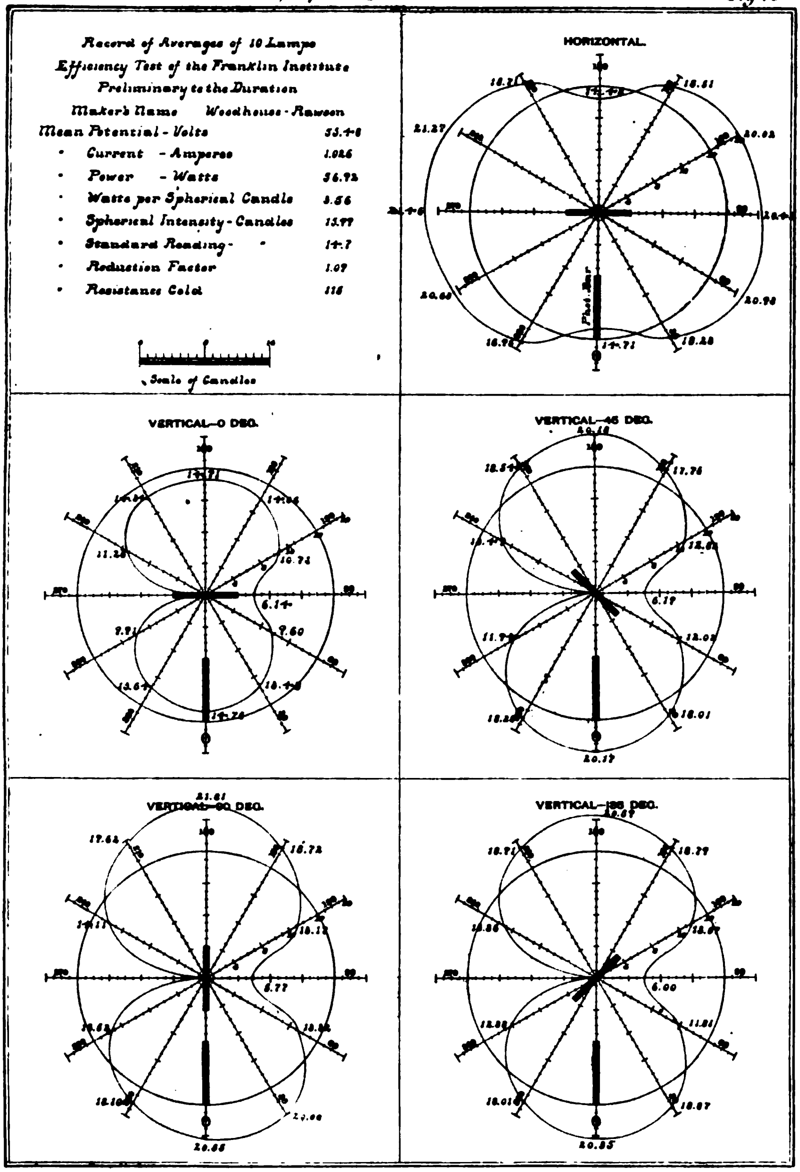
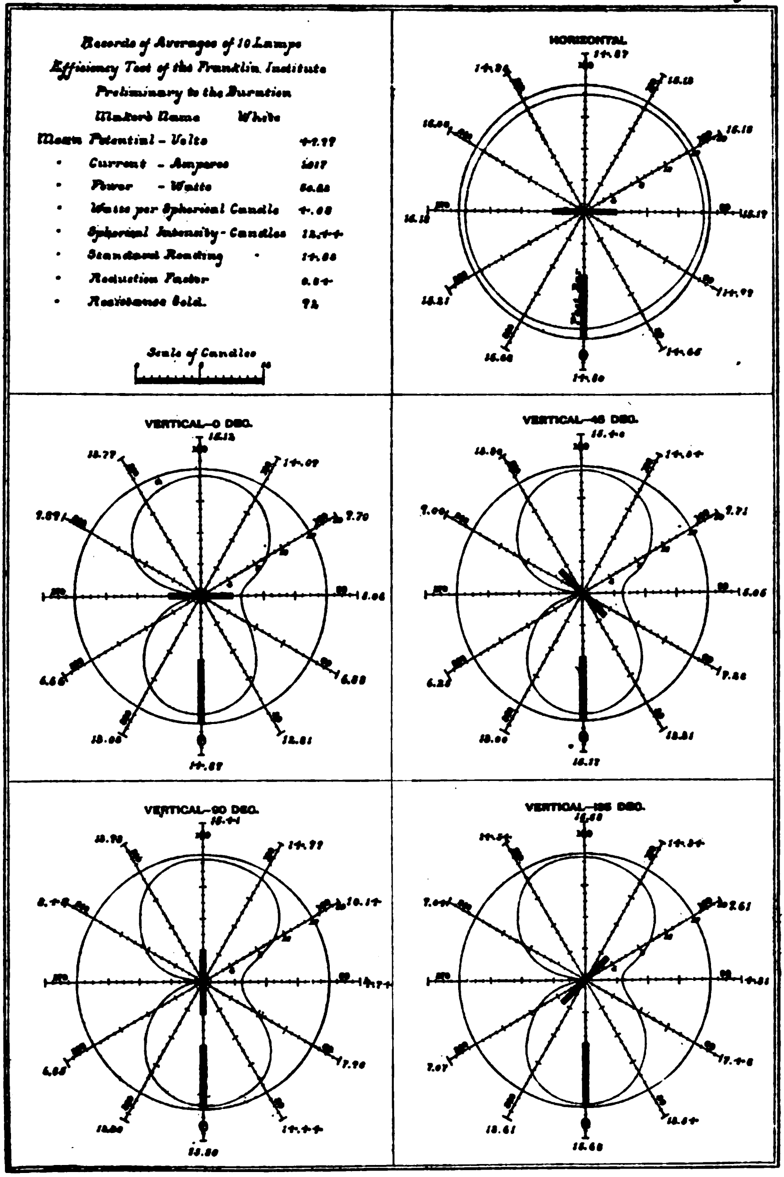
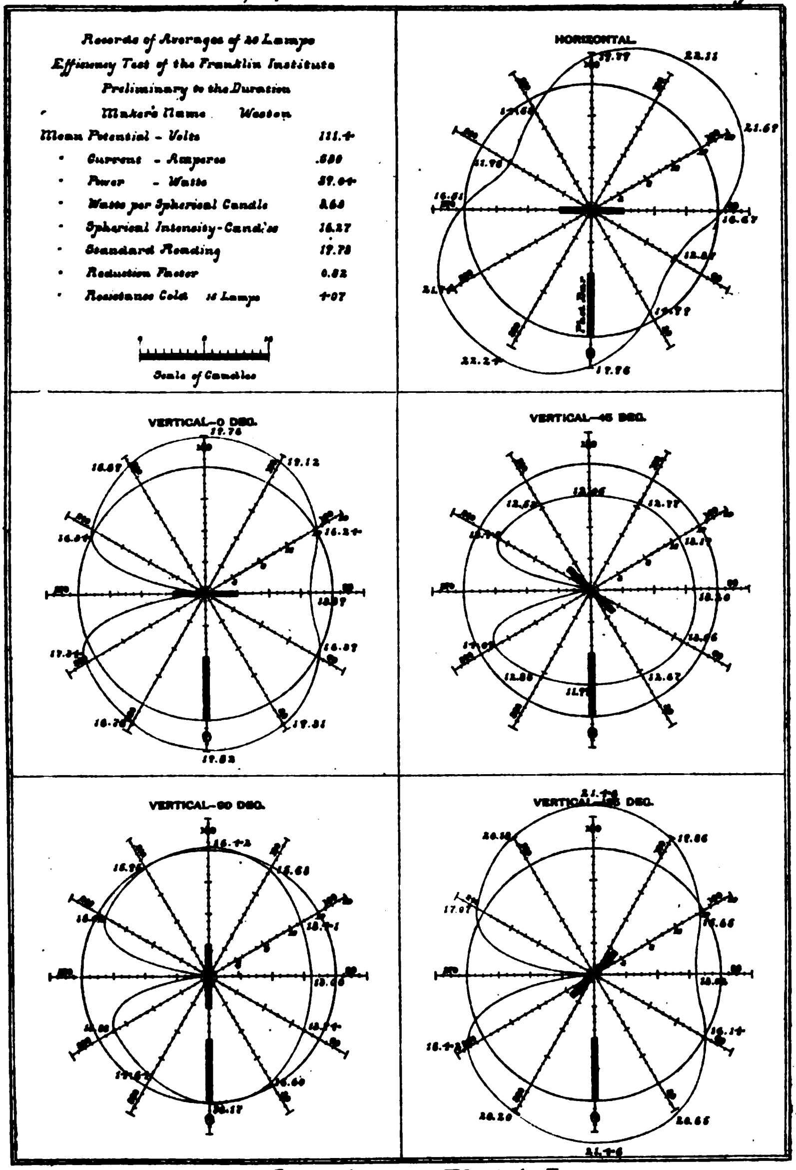


Test of Incandescent Electric Lamps.



Test of Incandescent Electric Lamps.



Test of Incandescent Electric Lamps.

sion that under the code no withdrawal is possible, and their letter of the 8th becomes invalid when questioned by a contestant.

J. B. MURDOCK, G. M. WARD,
L. DUNCAN, WM. D. MARKS.

Subsequently another letter was received from Mr. Weston and another conference held at his request, but the committee regarded their action as final and nothing was done.

The committee present the above as a matter of justice to Mr. Weston and also as an explanation of their own course of action.

Reference has already been made to the peculiar form of the Weston carbon. The light curves were very similar in form in all the lamps. In one, the major axis of the curve of horizontal illumination lay in the direction of 30°–210° instead of in 330°–150° as in the figure. In making up the average of twenty, another lamp was substituted for this one.

The results of the preliminary efficiency measurements are given in the following tables and diagrams.

WESTON LAMPS (70 VOLTS.).

Mr. Weston having expressed a desire to have measurements made on a lot of 70-volt paper carbon lamps, they were entered by the president of the FRANKLIN INSTITUTE for test. The distribution of light is almost exactly the same as in the other lot. Ten lamps were selected from a lot of thirty-three received from Mr. Weston, tested for efficiency and afterwards subjected to a duration test of 523 hours.

In addition to Mr. Weston's approval of the methods adopted in the test, as stated in his letter of February 18th, the committee received the following:

PHILADELPHIA, March 6th, 1885.

Having examined the methods of testing used and the results obtained in the efficiency test now being made by the FRANKLIN INSTITUTE, I am satisfied that the methods used are such as will produce correct results.

FRANCIS R. UPTON.

PHILADELPHIA, February 13, 1885.

Having been personally present during the determination of the efficiency of the lamps entered for the duration test, and having examined the instruments used, the methods pursued and the operations of the experimenters, I am of the opinion that the tests are fairly conducted and that the methods used are such as to produce correct results.

JOHN W. HOWELL.

Table II.—*Edison Lamps.*

Lamp.	Volts.		Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec. H.P.	
	Mk'd.	Obsrv'd.			Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
1	99	98·9	·690	68·24	15·31	18·81	4·45	260·	143·3	15·90	·96	....	....
2	98	98·9	·703	69·44	14·88	17·62	4·83	252·	140·7	13·95	1·08	....	....
3	95	95·8	·711	68·12	14·87	18·03	4·58	241·	134·7	16·82	·91	....	....
4	95	95·8	·718	68·79	15·72	19·44	4·37	244·	133·4	16·90	·93	....	....
5	97	97·8	·718	70·21	16·41	20·28	4·27	244·	136·2	17·82	·95	....	....
6	99	99·9	·692	69·13	14·67	17·98	4·71	264·	144·4	16·07	·91	....	....
7	95	95·8	·736	70·31	14·57	18·43	4·82	235·	130·2	16·50	·88	....	....
8	97	97·9	·729	71·37	16·81	20·32	4·24	239·	134·3	19·97	·84	....	....
9	95	95·8	·718	68·79	15·11	18·51	4·55	240·	133·4	15·10	1·00	....	....
10	97	97·8	·714	69·83	14·58	18·54	4·79	246·	137·0	14·92	·98	....	....
11	98	98·7	·711	70·18	16·66	20·98	4·21	250·	138·8	18·25	·91	....	....
12	98	98·8	·686	67·77	13·76	17·48	4·92	254·	144·0	14·72	·98	....	....
13	96	96·7	·723	69·91	15·44	19·00	4·52	235·	133·7	16·67	·93	....	....
14	96	96·7	·707	68·37	15·62	19·70	4·37	245·	136·8	16·63	·94	....	....
15	99	99·7	·692	68·99	15·65	19·74	4·40	255·	144·1	14·80	1·09	....	....
16	95	95·7	·714	68·33	16·09	20·26	4·24	239·	134·0	20·80	·79	....	....
17	98	98·8	·701	69·26	16·61	21·10	4·17	259·	140·9	17·98	·92	....	....
18	97	97·7	·708	69·17	15·60	19·25	4·43	242·	138·0	16·34	·96	....	....
19	99	99·7	·714	71·19	16·02	19·50	4·44	250·	139·6	16·15	·99	....	....
20	100	100·7	·696	70·09	15·82	19·56	4·43	256·	144·7	16·23	·97	....	....
21	97	97·7	·698	68·19	16·71	20·95	4·08	250·	140·0	17·27	·97	....	....
22	97	97·8	·719	70·32	16·13	20·36	4·36	241·	136·0	16·27	·99	....	....
23	97	97·0	·719	69·74	15·68	19·67	4·44	247·	135·2	19·00	·83	....	....
24	95	95·0	·705	66·98	15·04	18·57	4·45	238·	134·8	15·95	·94	....	....
25	98	98·7	·714	70·47	15·42	19·43	4·57	253·	138·2	14·92	1·03	....	....
26	96	95·9	·700	67·18	15·11	19·24	4·44	248·	137·0	15·95	·95	....	....
27	95	95·8	·668	64·00	15·38	19·20	4·17	259·	143·4	17·30	·89	....	....
28	99	99·8	·692	69·06	14·90	18·88	4·63	254·	144·2	16·70	·90	....	....
29	95	95·7	·697	66·70	15·24	18·88	4·87	243·	137·3	15·10	1·01	....	....
30	95	95·7	·696	66·61	14·97	18·42	4·45	244·	137·5	16·65	·90	....	....
31	98	98·0	·713	69·87	15·40	19·24	4·53	247·	137·4	15·40	1·00	....	....
....	96·9	97·57	·7065	68·92	15·47	19·24	4·459	247·5	....	....	....	160·2	210·4

Table III.—*Stanley Lamps, 96 Volts.*

Lamp.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec. H.P.	
				Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
26	96·4	·578	55·72	13·10	15·73	4·25	330·	166·8	15·85	·82	....	....
27	96·4	·538	51·86	10·25	12·33	5·06	359·	179·2	12·52	·82	....	....
28	96·5	·584	56·35	17·11	19·78	3·29	328·	165·2	19·80	·86	....	....
29	96·4	·537	51·76	16·49	19·48	3·14	368·	179·5	19·82	·83	....	....
30	96·3	·544	53·35	12·94	15·65	4·12	339·	173·8	15·35	·84	....	....
31	96·4	·529	50·99	9·91	12·49	5·14	357·	182·2	12·58	·79	....	....
32	96·5	·559	53·94	13·54	16·37	3·98	341·	172·6	15·90	·85	....	....
33	96·4	·528	50·90	14·32	17·17	3·55	365·	182·6	17·45	·82	....	....
34	96·4	·558	53·79	14·17	16·95	3·79	349·	172·8	17·05	·89	....	....
35	96·4	·552	53·21	13·72	16·59	3·87	350·	174·6	16·38	·82	....	....
36	96·2	·576	55·41	16·49	19·55	3·36	336·	167·0	19·92	·83	....	....
37	97·2	·534	51·90	14·28	17·29	3·63	350·	182·0	17·55	·81	....	....
41	97·2	·567	55·11	12·93	15·51	4·26	340·	171·4	15·97	·81	....	....
51	97·2	·578	56·18	11·01	13·28	5·10	320·	168·2	13·52	·81	....	....
	96·56	·554	53·61	13·59	16·30	4·04	345·1	....	....	......	189·1	226·3

Table IV.—*Stanley Lamp, 44 Volts.*

Lamp.	Volts.	Ampéres.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Standard Reduc'n		Candles per Elec. H.P.	
				Mean. Spherical.	Mean Horizont'l		Cold.	Hot.	Reading.	Factor.	Spherical.	Horizont'l
1	44·40	1·096	48·66	12·39	15·36	3·92	80·7	40·51	15·2	·82	....	....
2	44·45	1·039	46·18	11·10	13·38	4·16	84·0	42·78	14·0	·79	....	....
3	43·90	1·068	46·88	15·88	19·46	2·95	79·5	41·10	19·7	·81	....	....
4	43·90	1·080	47·41	14·07	17·40	3·36	79·2	40·65	18·3	·77	....	....
6	43·90	1·001	43·94	10·31	12·58	4·26	85·0	43·86	13·1	·79	....	....
7	43·90	1·078	47·32	12·46	15·15	3·79	78·0	40·72	15·5	·80	....	....
8	43·90	1·044	45·83	10·58	12·92	4·33	79·8	42·05	12·1	·87	....	....
9	43·80	1·036	45·37	16·29	19·59	2·78	83·0	42·28	20·4	·80	....	....
10	43·75	1·031	45·10	15·94	19·29	2·83	82·4	42·43	19·3	·83	....	....
11	43·90	1·059	46·49	15·19	19·28	3·06	79·0	41·45	19·1	·80	....	....
	43·98	1·053	46·32	13·42	16·44	3·544	81·1	......	......	......	216·1	264·8

TABLE V.—*Woodhouse and Rawson Lamps, 55 Volts (1st lot).*

Lamp.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec. H.P.	
				Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
1	55·30	1·162	64·26	19·01	22·14	3·38	98·	47·59	17·7	1·07	....	....
2	55·30	·871	48·16	12·42	15·08	3·87	132·	63·49	10·8	1·15	....	....
3	55·20	1·162	64·14	20·06	24·39	3·19	102·	47·50	17·6	1·14	....	....
4	55·15	1·057	58·29	17·99	21·27	3·24	108·	52·18	17·2	1·05	....	....
5	55·40	1·000	55·40	13·97	16·31	3·96	118·	55·40	12·3	1·14	....	....
6	55·30	·936	51·76	13·11	14·76	3·94	124·	59·08	11·7	1·12	....	....
7	55·90	·914	51·09	15·53	19·45	3·29	132·	61·16	15·5	1·00	....	....
8	56·05	1·025	57·45	15·05	18·28	3·81	110·	54·68	14·0	1·07	....	....
9	55·95	1·125	62·94	18·43	22·01	3·41	106·	49·73	18·5	1·00	....	....
10	56·00	·805	45·08	12·19	14·38	3·69	139·	69·57	10·4	1·18	....	....
18 B	55·25	1·004	55·47	14·38	17·41	3·87	115·	55·03	12·0	1·19	....	....
....	55·53	1·006	55·82	15·64	18·68	3·605	117·3	....	......	......	209·0	249·6

Table VI.—*Woodhouse and Rawson (2d lot).*

Lamp.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec. H.P.	
				Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
30	55·00	1·167	64·18	18·52	22·73	3·46	100·	47·13	17·18	1·08	....	....
31	55·05	1·182	65·07	17·28	20·93	3·76	102·	46·57	18·48	·94	....	....
32	55·00	1·195	65·72	17·36	21·28	3·78	100·	46·02	16·28	1·07	....	....
33	55·05	1·188	65·40	19·01	22·67	3·44	101·	46·34	19·05	1·00	....	....
34	55·00	1·147	63·08	16·91	20·78	3·73	100·	47·95	16·68	1·01	....	....
35	54·95	1·139	62·58	19·56	23·53	3·20	101·	48·24	21·14	·93	....	....
36	55·00	1·191	65·50	21·41	25·98	3·05	99·	46·18	22·13	·97	....	....
37	55·00	1·185	65·17	18·74	22·93	3·47	100·	46·41	18·08	1·04	....	....
38	54·95	1·197	65·77	17·84	20·70	3·69	100·	45·91	18·05	·99	....	....
39	55·00	1·186	65·28	16·33	19·74	3·99	99·	46·37	15·50	1·05	....	....
	55·00	1·178	64·77	18·30	22·13	3·56	100·2	....	....	......	210·8	254·9

Note.—These lamps were marked 50 volts.

Table VII.—*White Lamps, 50 Volts.*

Lamp.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec. H.P.	
				Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
1	50·00	1·033	51·65	10·80	13·08	4·78	....	48·40	12·78	·85	....	....
2	50·00	1·005	50·25	10·97	13·20	4·58	....	49·75	12·93	·85	....	....
3	50·00	·928	46·40	9·09	11·08	4·05	....	53·88	10·75	·85	....	....
4	49·95	1·020	50·95	14·17	17·17	3·59	....	48·97	16·75	·85	....	....
5	50·00	·995	49·75	14·31	17·05	3·47	....	50·25	17·00	·84	....	....
6	50·00	1·047	52·35	14·64	17·55	3·57	....	47·76	17·38	·84	....	....
7	50·00	1·001	50·05	13·99	16·98	3·57	....	49·95	16·46	·85	....	....
8	50·00	1·025	51·25	11·69	14·23	4·38	....	48·78	14·13	·83	....	....
9	50·00	1·206	60·30	13·22	15·92	4·56	....	41·46	15·95	·83	....	....
10	49·95	·908	45·35	11·55	14·26	3·92	....	55·01	14·20	·81	....	....
	49·99	1·017	50·83	12·44	15·05	4·05	......	....	....	......	182·6	220·9

* An error was made in measuring resistance cold, which was not discovered in time for correction.

Table VIII.—*Weston Lamps, 110½ Volts.*

Lamp.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec.H.P.	
				Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
1	111·3	·519	57·76	17·49	19·36	3·30	....	214·5	20·10	·87	....	....
2	111·0	·530	58·83	14·16	15·37	4·15	....	209·4	16·72	·85	....	....
3	111·3	·502	55·87	14·28	15·77	3·82	....	221·7	16·32	·87	....	....
4	111·6	·546	60·93	12·70	13·81	4·79	....	204·4	16·20	·78	....	....
5	111·5	·537	59·87	16·01	17·53	3·74	....	207·6	18·18	·88	....	....
6	111·5	·501	55·86	11·25	12·18	4·96	402·	222·6	14·00	·81	....	....
7	111·5	·543	60·54	18·32	20·10	3·30	414·	205·3	21·95	·88	....	....
8	111·5	·523	58·31	20·23	22·54	2·88	423·	213·2	21·88	·92	....	....
9	111·4	·530	59·04	16·53	17·97	3·57	409·	210·2	21·90	·75	....	....
10	111·5	·529	58·98	19·08	20·82	3·09	421·	210·8	22·15	·86	....	....
11	111·4	·513	57·14	16·16	17·86	3·53	400·	217·2	21·04	·77	....	....
12	111·5	·553	61·66	22·26	24·45	2·77	408·	201·6	25·68	·87	....	....
13	111·5	·531	59·20	16·27	18·13	3·63	407·	210·0	20·30	·80	....	....
14	111·4	·549	61·15	19·14	21·31	3·19	409·	202·9	24·65	·78	....	....
15	111·4	·491	54·69	9·78	10·45	5·59	408·	226·9	11·97	·82	....	....
16	111·4	·518	57·14	15·08	16·43	3·80	399·	217·2	18·12	·83	....	....
17	111·5	·521	58·09	12·23	14·08	4·75	404·	214·0	15·35	·80	....	....
18	111·4	·540	60·15	16·71	17·95	3·60	405·	206·3	20·97	·80	....	....
19	111·4	·561	62·49	20·30	22·93	3·07	402·	198·6	27·95	·73	....	....
20	111·4	·562	62·60	19·44	20·88	3·22	392·	198·2	21·68	·90	....	....
21	111·4	·528	58·81	17·02	18·03	3·45	409·	211·0	19·65	·87	....	....
23	111·5	·536	59·76	17·44	19·92	3·42	400·	208·0	22·68	·77	....	....
24	111·3	·530	58·99	16·08	17·71	3·77	421·	210·0	18·02	·89	....	....
	111·42	·530	59·04	16·43	18·07	3·713	407·9	....	......	......	209·8	230·7

Table IX.—*Weston Lamps, 70 Volts.*

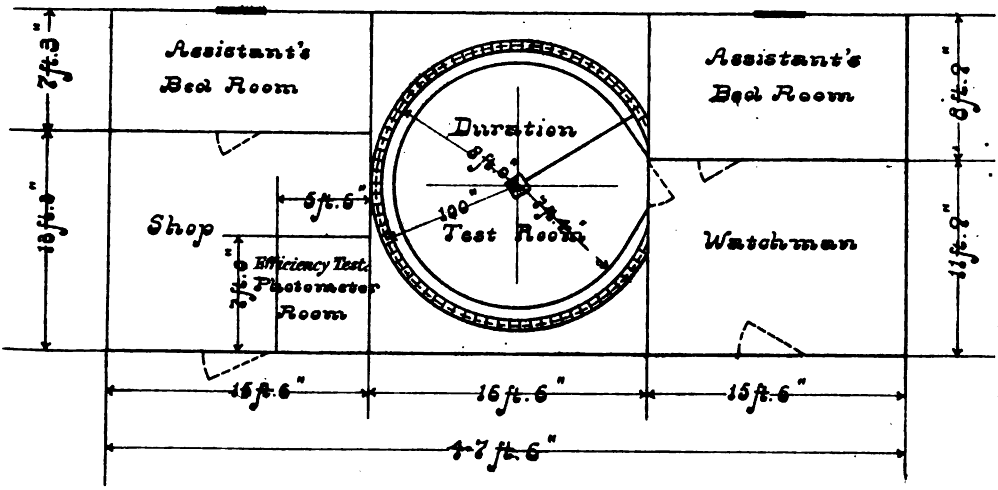
Lamp.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Resistance.		Stand'rd Reading.	Reduc'n Factor.	Candles per Elec. H.P.	
				Mean Spherical.	Mean Horizont'l		Cold.	Hot.			Spherical.	Horizont'l
51	70·2	·963	67·60	14·53	16·22	4·65	152·	72·90	17·35	·84	....	....
54	70·4	·959	67·51	14·46	15·73	4·66	149·	73·41	17·33	·83	....	....
55	70·4	1·002	70·54	17·11	18·83	4·12	144·	70·26	20·80	·82	....	....
56	70·4	·969	68·21	15·07	16·96	4·52	148·	72·65	18·10	·83	....	....
58	70·5	·952	67·11	16·95	18·67	3·96	153·	74·05	19·80	·86	....	....
59	70·4	·944	66·45	16·04	18·12	4·14	152·	74·58	19·78	·81	....	....
61	70·3	·969	68·12	13·06	14·23	5·21	153·	72·55	15·48	·84	....	....
62	70·4	·971	68·35	14·42	16·03	4·74	148·	72·50	18·02	·80	....	....
63	70·4	·984	69·27	14·85	16·93	4·66	147·	71·54	18·35	·81	....	....
64	70·4	·962	67·72	15·32	16·76	4·42	140·	73·18	18·00	·85	....	....
....	70·4	·968	68·09	15·18	16·85	4·51	150·	....	18·30	......	166·3	184·6

TEST FOR DURATION.

For the duration test proper the three rooms of the Brush exhibit during the exhibition were utilized. The arrangements are shown in Fig. 13. The lamps were placed in boxes arranged in a circle in the middle room, which was securely boarded up, with the exception of one door opening into the watchman's room. This door was securely locked and sealed, except when measurements or adjustments were being made. A glass pane set in it (Fig. 14) allowed of inspection of the lamps when the door was closed. On the opposite side of the duration test room was a shop in which all necessary electrical work was done. In a corner was the photometer room, containing the photometer used in the efficiency measurements (Figure 6). The two rooms marked as assistants' bed rooms were permanently occupied by the assistants connected with the test, Mr. A. L. Church, who was in charge in absence of members of the committee, and Mr. C. E. Billberg. The exhibition building around the three rooms was well lighted by extra lamps in circuit, and the whole was under the inspection of a watchman. When the committee finished their daily work in the duration test room, the door was locked and sealed in the presence of one of the committee and remained closed until the next day, when the seal was examined before the room was opened. It was always found intact. While the room was closed, inspection of the lamps was made through the glass set in the door. These inspections were made every half hour, and whenever a lamp was observed to be out the time was recorded. The lamp was examined the next time the room was opened, and removed if found to be broken. It was feared that lamps might be accidentally broken, and provision was made in the code for replacing such lamps by others. In order to avoid breakage the lamps were never touched except to adjust their position in the socket, or to remove dust which had settled on them. Only one lamp (Stanley No. 12), was accidentally broken in the test, and this occurred while making a connection, by accidentally touching its leading wire to the binding post of the next lamp, giving the lamp 96 volts instead of the 44 required. When the room was open, no one not connected with the test was allowed to enter it unless accompanied by a member of the committee.

The arrangements in the duration test room may be understood from Figs. 15 and 16, the former being from a drawing and the latter being a longitudinal section through the lamp boxes. The lamps were

Plan of test Rooms.



Test of Incandescent Electric Lamps.

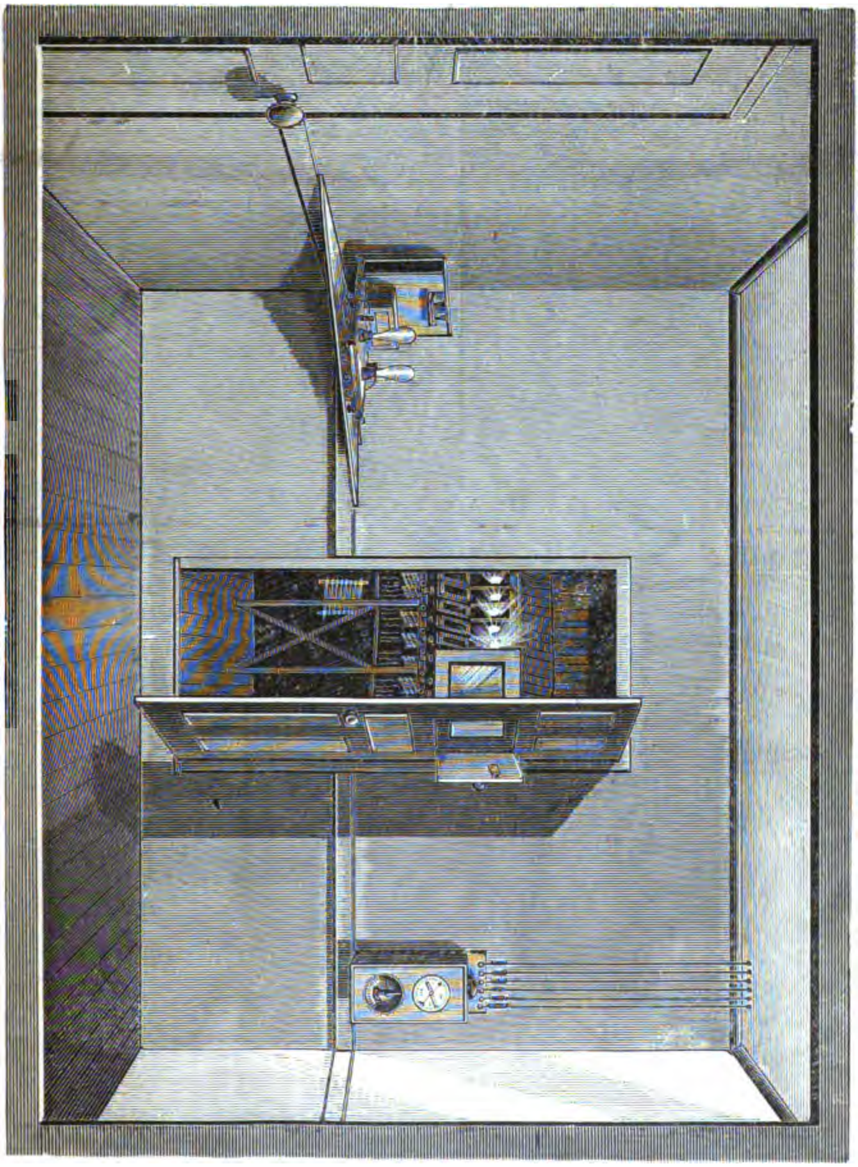


FIG. 14.—Test room from Watchman's room.

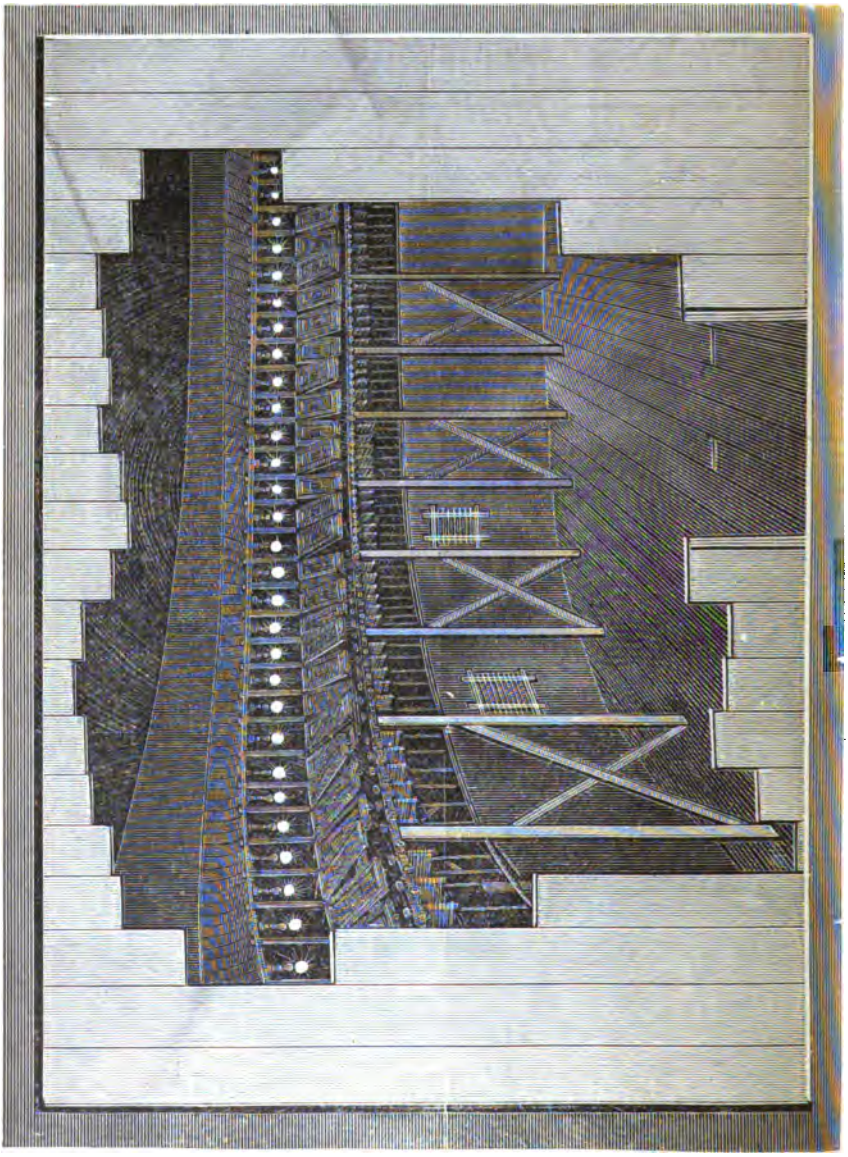
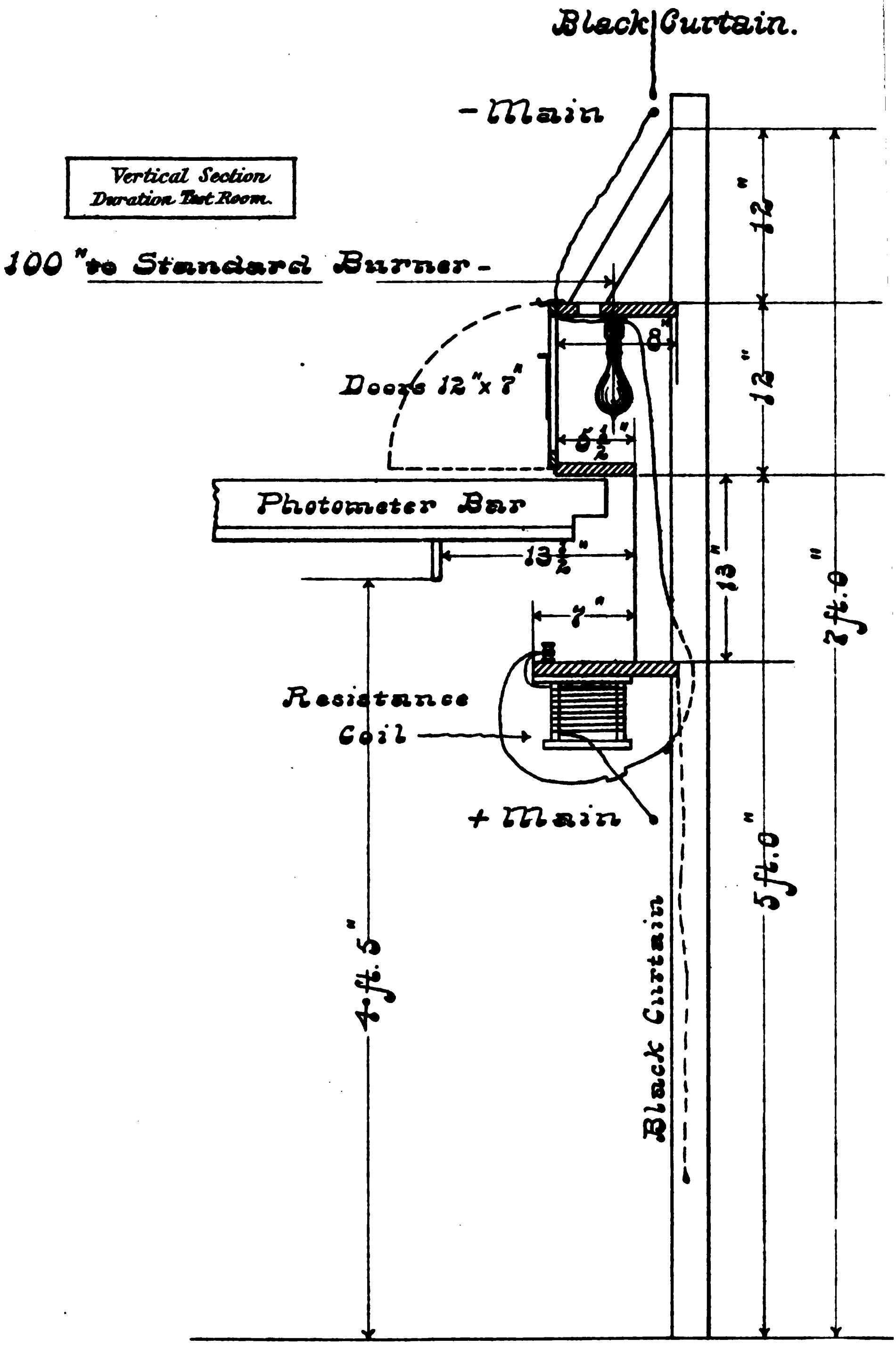


FIG. 15.—Duration test room.



Test of Incandescent Electric Lamps.

arranged in a circle of one hundred inches radius, the centre of which was occupied by the slit of the Methven burner. This distance was carefully measured and verified. The circle contained boxes for seventy-one lamps, each box being eight inches wide. The lamp sockets were screwed to brass nipples on the hundred-inch curve. Each box had a door which opened inward and downward. In Fig. 15 the doors are down, in Fig. 17 they are closed. The details of the boxes are shown in Fig. 16. The lamp is seen in its box with the door closed. The back of the box is open, the escape of light in that direction being deadened by reflection on the blackened wall of the room, and still further prevented from affecting the photometer disc by curtains above and below the lamps. Each box contained an opening in its top of two inches wide and six inches in length, for the purpose of assisting in carrying off hot air. The rear portion of the lower shelf was also cut away to assist in producing a vertical air current, when the box was closed. The middle and lower shelves of the plan were connected by a blackened sheet of heavy pasteboard. The doors and the partitions separating the boxes were made of sheet zinc. Each lamp circuit lay in a vertical plane. One of the lamp leads passed from the upper main down through a slot in the upper shelf into the box to the socket. The other passed through the opening in the lower part of the box down behind the pasteboard to a binding post on the lower shelf. These posts were placed on a strip of wood, not shown in the figure, covered with several coats of shellac, and fastened by pins to the front edge of the shelf. This strip was kept wiped clean from dust or anything that might cause leakage over its surface. To the binding post was also connected one end of the adjustable German-silver resistance, the other end being soldered to the lower main. The reels were of different sizes, the largest being about twelve inches square and two inches wide. Cotton insulated German-silver wire was used, the size varying from 22 to 26, American gauge. The turns were loosely wound on the reel, and the air cooling was in all cases sufficient, no charring of the insulation or short circuiting of the wire occurring. Some of the lamps required as much as three hundred feet of wire to procure adjustment of potential. The spare wire of each reel was wound on a spool fastened to the front side of the shellaced strip. The mains were supported by porcelain insulators, and after the leading wires had been soldered were wrapped with rubber tape. The inside of the room being lampblacked throughout, a slight leak was sometimes

perceptible from the upper main to the ground, but the insulation resistance between the mains through the lamp sockets and between the upper main and the brass terminals was tried both before and after the test and found to be practically infinite, no deflection being perceptible with an E. M. F. and galvanometer, capable of indicating thirty megohms.

The duration test room was ventilated by large holes, cut both in the roof and in the floor. The temperature of the room averaged about 3°C. above that of the air in the building. The temperature of the boxes was frequently tested and found to be about 16°C. above the rest of the room, rising to 18° when the doors were closed. The highest temperature of the room during the test was 33·5°C.

The photometer arrangements are shown in Fig. 17, the door of the central box carrying the Methven standard being shown open. Each box door contained a slot cut to the size of the carbon of the lamp in the box. This slot was covered by a movable shutter. It was found, however, that as a rule the reflection from the walls back of the boxes was inappreciable on the photometer and measurements were generally made with doors down, it being thought better that any extra light should be in favor of the lamp, than that risk should be run of cutting off any light by errors in size or shape of the slot or in displacement of the door due to the continual handling.

The general method of daily work was as follows: The forenoon was devoted to calibration of the potential galvanometer, to adjustments of potential of the lamps by means of the German-silver resistances, and to the calculation and recording of the previous day's work. The photometric measurements were made in the afternoon. This was varied to suit circumstances. Three persons took part in each observation. The lamp was first put in circuit with the current galvanometer. This was done by disconnecting the lower leading wire of the lamp from the binding screw and connecting it to one of the leads of the current galvanometer by a connector, to which was also fastened one of the potential leads, the other being on the upper main. The return lead from the current galvanometer was clamped to the binding post on the shellaced strip. The tangent galvanometer and its leads were thus in circuit with the lamp, but as the resistance of both was less than a tenth of an ohm, the increased resistance of the circuit was not more than $\frac{1}{500}$ of the lowest resistance lamp tested. After the connections were completed ten photometric measurements were made

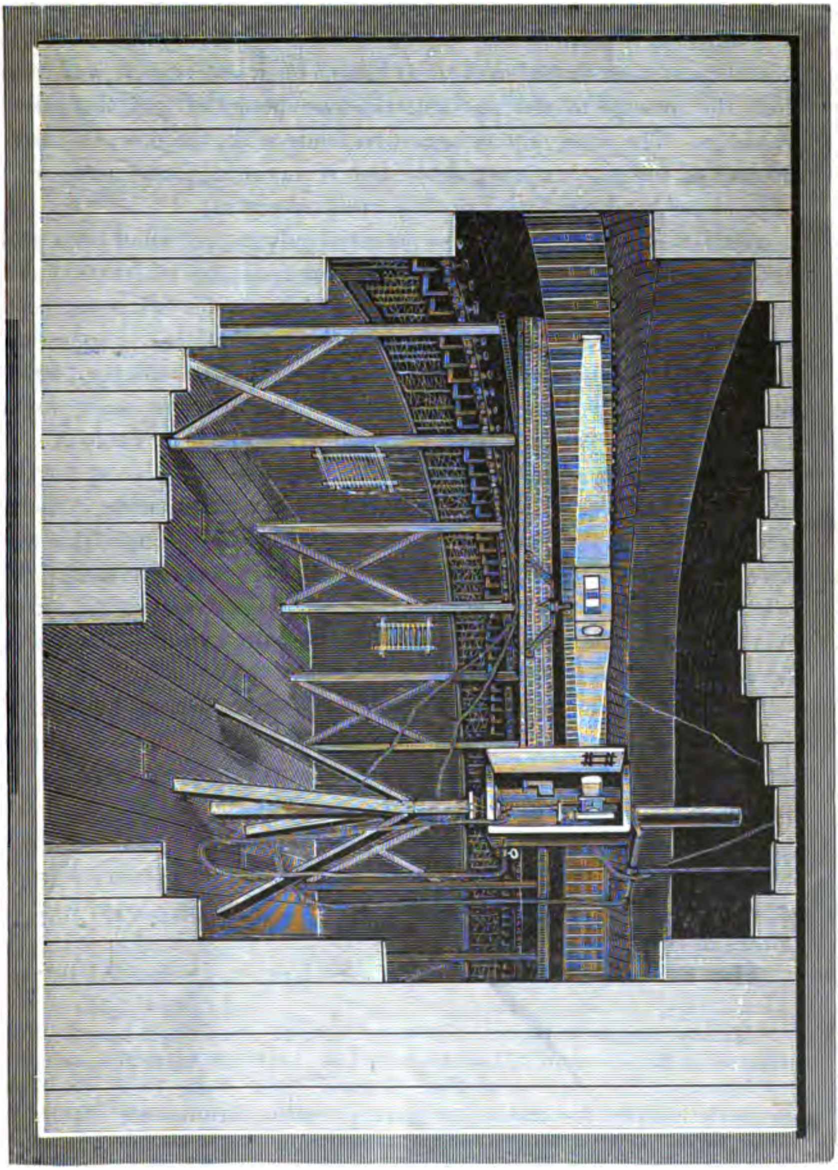


Fig. 17—Photometer arrangements—duration test room.

and the mean taken as the candle-power. Two observers read the galvanometers, a double reading of the potential galvanometer being made with the currents in the tangent in each direction. As soon as the electrical measurements were finished a signal was made and the connections were shifted to the next lamp. Each observation was, therefore, the average of ten photometric, four potential and two current readings. The observations were first made with the potential under control of the automatic regulator, but it was soon found necessary to depend on hand regulation during measurements.

A series of calibrations of the potential galvanometer had been made before the test for duration commenced. A resistance of 100,000 ohms was used in this test in the galvanometer circuit for all potentials of seventy volts or less, and 150,000 for higher potentials. The preliminary series gave a constant of 3·615 for 100,000 and 5·436 for 150,000 at the mean temperature of the room. The calibrations made during the test and the constants used day by day are given in Table X.

The observations were calculated so far as was possible at the time of observation, each observer making his own calculation. As the average time of observation on each lamp was three minutes, this work was very much hurried. Tabulated forms were generally used. The whole of the day's work was gone over again from the original records in the evening and the next morning, and results were finally reviewed by another computer after the test was finished.

In reviewing the results of the test, the committee note discrepancies in the candle-power. From the continuous nature of the test, no repetition of the work was possible, and the discrepancies referred to were shown to be such, only by observations on subsequent days. Under these circumstances no verification could be made. In order to facilitate comparison they feel justified in rejecting the observations of April 25, 27, 28, 29* and May 15 and 25,† as not in accord with the others of the series.

After the test, the discoloration of each lamp was estimated by com-

* Marked magnetic disturbances were reported from the magnetic observatories at Toronto and at Los Angeles, Cal., between April 25th and 29th.

† Through the courtesy of Prof. Hilgard, Supt. of the U. S. Coast and Geodetic Survey, the committee have since the termination of the test received a complete set of tracings recorded by the bi-filar magnetometer at the Magnetic Observatory at Los Angeles, Cal. These tracings show marked variations of H. on April 26th, 27th, 28th, and May 25th, which might partially account for the discrepancies on those days.

TABLE X.—*Results of Calibrations of Potential Galvanometer.*

Date.	Constant for 100000	Constant for 150000	Constants used 100000	Constants used 150000	Date.	Constant for 100000	Constant for 150000	Constants used 100000	Constants used 150000
					May.				
11	3·619	5·423	....	......	7	3·597	5·396	3·60	5·41
12	....	....	....	......	8	3·586	5·388	3·59	5·40
13	....	....	3·615	5·44	8	3·590	5·399	......	......
14	3·620	....	3·615	5·44	9	3·604	5·417	3·60	5·41
15	3·615	....	3·615	5·44	10	3·596	....	3·61	5·42
16	3·612	....	3·615	5·44	11	3·600	5·405	3·60	5·41
17	3·625	....	3·615	5·44	12	3·608	5·432	3·61	5·42
18	3·620	....	3·615	5·44	13	3·610	5·422	3·61	5·42
19	3·626	5·457	3·615	5·44	...	3·601	5·424	......	......
20	3·615	5·436	3·615	5·44	14	3·604	5·408	3·61	5·42
21	3·620	....	3·615	5·44	...	3·611	5·422	.....	......
22	3·613	....	3·615	5·44	15	3·612	5·415	3·61	5·41
23	3·611	....	3·615	5·44	16	3·607	5·416	3·61	5·41
24	3·602	5·432	3·615	5·44	17	....	....	3·61	5·41
25	3·611	....	3·615	5·54	18	3·597	5·412	3·60	5·41
26	....	....	3·615	5.44	...	3·601	5·412	......	......
27	3·596	....	3·600	5·43	19	5·605	5·412	3·605	5·41
...	3·605	5·427	....	......	...	3·608	5·427	......	......
28	3·606	....	3·61	5·43	20	3·598	5·412	3·60	5·41
29	3·609	....	3·61	5·43	21	3·591	5·402	3·60	5·41
30	3·607	5·439	3·61	5·43	...	3·597	5·416	......	......
...	....	5·431	....	......	22	3·585	5·393	3·59	5·41
May.					...	3·595	5·411	......	......
1	3·607	5·398	3·61	5·43	23	3·585	....	3·59	5·40
1	3·602	5·418	....	......	...	3·586	....	......	......
...	....	5·423	....	......	24	3·591	5·406	3·59	5·40
2	3·614	5·434	3·61	5·43	25	3·601	....	3·59	5·40
3	....	....	3·61	5·43	...	3·593	5·388	......	......
4	3·602	5·412	3·61	5·43	...	....	5·408	......	......
5	3·616	5·431	3·61	5·43	28	....	5·390	......	......
6	3·606	5·416	3·61	5·43					

parison with six lamps taken as standards. Number one showed the least discoloration, and number six the greatest, the latter having its carbon destroyed by too high a potential.

The committee present the following summary of the results (Tables XI–XVII): Whenever the candle-power was observed at too high or too low potential, the former is reduced to what it would have been at normal potential by such an allowance as seems proper, the general rules being given for each lot of lamps. These values are derived from the data given in the tables of efficiency and duration, aud are believed to be substantially correct.

EDISON. (TABLE XI.)

In allowing for the potential being other than normal, one volt is assumed to cause a difference of mean horizontal intensity of one candle. The whole lot of lamps behaved with great uniformity, there being in all a gradual increase of resistance throughout the test.

STANLEY-THOMPSON. (TABLES XII, XIII.)

The same allowance is made for candle-power per volt with 96-volt lamps as with the Edison. In correcting the 44-volt lamps, an allowance of one and a half spherical candles is made for one volt. The test of the latter was not perfectly satisfactory, as most of the lamps were connected two in series. The only adjustment of potential possible was the sum of the potentials of the two lamps, and as soon as the resistance of the lamps began to change, one of each pair was at a higher potential than normal, the other lower. As soon as possible the lamps were placed in separate circuits. The average potential of each lamp during its life, taken from the daily observations of potential is given in the table to assist in interpreting the results. Number 3 lamp in particular was tested at so high a potential that it was thought best to introduce another, and number 12, which had never been measured for efficiency, was tested for life, but was accidentally destroyed after 307 hours.

WOODHOUSE AND RAWSON. (TABLE XVI.)

The allowance for these lamps is one and a half spherical candle per volt, that being about the average of ten lamps tested at two different potentials. Most of the first lot tested were connected two in series, and the same objection holds here as with the Stanley-Thompson

lamps. The committee were very willing, therefore, to test a second lot of lamps, which were placed in separate circuits from the start. The resistance of this second lot gradually decreased for three days, the candle-power rising, and then falling as the resistance increased. All the lamps were much discolored.

WHITE. (TABLE XV.)

This set of lamps changed greatly in their candle-power. Every lamp decreased in resistance, the average decrease being two and a half ohms in about one hundred hours, the candle-power increasing greatly. The resistance then began to increase and the candle-power to fall off, but after 250 hours the candle-power was still higher than in the preliminary efficiency test. In correcting, the allowance of one and a half spherical candles per volt is made.

WESTON (110½ VOLT). (TABLE XVI.)

The action of these lamps is shown by the tables of daily observations. As predicted by Mr. Weston, they increased rapidly in resistance at first, the candle-power falling greatly. The correction of one spherical candle per volt is assumed in correcting these lamps.

WESTON (70 VOLT). (TABLE XVII.)

A difficulty was experienced with all the Weston lamps in getting the point of 0° lat. 0° long. exactly towards the photometer. Owing to the peculiar oblique position of the major axis of the curve of horizontal illumination, in relation to the plane of the carbon shanks, a slight rotation of the lamp in its socket materially affected the photometer reading. The fall of candle-power in number 62 may have been partially due to this, as the attempt was made on May 5th to adjust it. The increase of resistance, however, shows a deterioration in the lamp as well. The resistance of these lamps as a whole remained about constant, the changes being but slight in either direction, The correction allowed is one and three-tenths spherical candle per volt, determined by measurements of a lamp at different potentials.

The daily records of the lamps are appended (page 56, *et seq*). The calculations have been carefully revised. The first line of each lamp record contains the results of the preliminary efficiency measurements. The entries of candles under date of April 11, are the results of photo-

meter readings at the beginning of the test. The resistances had all been adjusted previously but it was thought desirable to check with the photometer that no lamp might be forced by an accidental high potential. The asterisks against the dates show that the observations made on those days are rejected as not in accordance with others of the series. The time is recorded in hours and minutes, to the nearest quarter of an hour.

Edison Lamps. (TABLE XI.)

Lamp.	Hours of test	Life of lamp.	Candles. Efficiency measurements. Spher'l.	Horiz'l.	Candles. Spher.	Horizontal.		Discoloration.
1	1,066	Survived.	15·3	18·8	9·3	11·4	After 1006 hours.	3
2	1,065	"	13·6	16·7	9·9	12·2	" " "	2
3	"	"	14·2	17·2	9·7	11·7	" " "	2
4	"	"	15·0	18·6	9·6	11·9	" " "	2½
5	"	"	15·7	19·5	10·5	13·0	" " "	2½
6	"	"	14·0	17·1	10·3	12·7	" " "	2½
7	"	"	14·0	17·6	9·3	11·7	" " "	2½
8	"	"	16·0	19·4	10·1	12·2	" " "	3
9	"	"	14·4	17·7	9·7	11·9	" " "	2½
10	"	"	14·0	17·7	9·8	12·4	" " "	2
11	"	"	16·1	20·3	9·8	12·4	" " "	3
12	"	"	13·1	16·7	10·3	13·1	" " "	2
13	"	"	14·9	18·3	10·1	12·4	" " "	2½
14	"	"	15·1	19·0	9·8	11·7	" " "	3
15	"	295	15·1	19·0	12·4	15·6	" 260 "	2
16	"	Survived.	15·5	19·6	9·8	11·7	" 1006 "	2½
17	"	"	16·0	20·3	8·9	11·3	" " "	3
18	"	"	15·0	18·5	9·0	11·1	" " "	2½
19	"	"	15·4	18·8	9·5	11·6	" " "	2½
20	"	"	15·2	18·9	9·0	11·2	" " "	2

Stanley-Thompson Lamps, 96 Volts. (TABLE XII.)

Lamp.	Hours of test.	Life of lamp.	Candles in efficiency tests. Spher'l.	Horiz'l.	Candles. Spher.	Horizontal.		Discoloration.
26	1,065	78	12·8	15·4	12·3	14·7	After 58 hours.	2
28	"	233	16·7	19·3	9·2	11·0	" 218 "	3
29	"	176	16·2	19·1	10·1	11·3	" 172 "	3½
30	"	Survived.	12·7	15·4	6·2	7·5	" 1000 "	3
33	"	257	14·0	16·8	8·3	9·8	" 241 "	2
34	"	525	13·9	16·6	8·5	10·2	" 502 "	3½
35	"	100	13·2	16·2	10·4	12·7	" 100 "	2
36	"	301	16·3	19·4	8·4	10·0	" 241 "	3½
37	"	882	13·4	16·1	6·5	7·8	" 837 "	2½
41	"	683	11·9	14·3	7·9	9·5	" 670 "	2½

Stanley-Thompson Lamps, 44 Volts. (TABLE XIII.)

Lamp.	Hours of test.	Life of lamp.	Average Potent'l.	Candles in efficiency test.		Candles.			Discoloration.
				Spher'l.	Horiz'l.	Spher.	Horizontal.		
1	1,065	309	43·60	11·8	14·6	6·6	7·8	Af'r 290 h.	4½
2	"	143	44·40	10·4	12·5	10·2	12·8	" 101 "	3½
3	"	187	46·85	16·0	19·7	8·0	9·8	" 101 "	4½
4	"	178	43·96	14·2	17·6	9·0	11·2	" 173 "	4½
6	"	288	43·85	10·4	17·1	6·8	8·3	" 280 "	3½
7	"	308	42·40	12·6	15·4	9·5	11·6	" 283 "	4
8	1,047	Survived.	43·65	10·8	13·2	5·4	6·6	" 987 "	4
9	1,065	40	....	16·6	19·9	....	....	....	2½
10	"	206	43·20	16·3	19·7	10·0	12·1	Af r 202 h.	3½
11	"	275	44·10	15·3	19·4	6·5	8·3	" 265 "	4½
12	865	307*	....	11·0†	....	9·2	....	" 307 "	6

* Accidentally destroyed. † Standard reading. No reduction factor.

Woodhouse and Rawson Lamps. (TABLE XIV.)

Lamp.	Hours of Test.	Life of lamp.	Average Potent'l.	Candles in efficiency tests.		Candles.			Discoloration.
				Spher'l.	Horiz'l.	Spher.	Horizontal.		
1	1,065	41	....	18·5	21·5	....	....	....	3½
3	1,065	214	55·60	19·7	24·0	13.0	15·9	Af'r 213 h.	4½
4	1,065	203	54·90	17·8	21·0	12·3	14·5	" 170 "	4½
5	1,065	440	54·55	13·3	15·6	10·4	12·2	" 289 "	4½
6	1,065	395	54·15	12·7	14·4	10·9	12·3	" 289 "	4
7	1.065	423	55·80	14·2	17·7	10·1	12·6	" 289 "	4½
8	1,065	118	55·75	13·6	16·5	12·8	15·5	" 78 "	3
9	1,065	716	55·00	17·0	20·4	6·6	7·8	" 716 "	5
10	1,065	69	55·20	10·8	12·7	12·4	14·6	" 82 "	2½
18B	1,065	278	55·15	14·0	16·9	13·3	16·1	" 266 "	3½
30	332	Survived.	....	18·5	22·7	14·8	18·3	" 273 "	4
31	332	227	....	17·2	20·9	14·5	17·5	" 200 "	4
32	332	Survived.	....	17·4	21·3	13·9	17·1	" 272 "	3½
33	331	"	....	19·0	22·7	14·6	17·4	" 272 "	4
34	331	235	....	16·9	20·8	16·5	20·3	" 200 "	3
35	331	272	....	19·6	23·5	13·5	16·2	" 272 "	3½
36	331	Survived.	....	21·4	26·0	12·4	15·0	" 272 "	4
37	331	177	....	18·7	22·9	17·6	21·5	" 151 "	3½
38	331	224	....	17·9	20·8	17·0	19·7	" 200 "	4½
00	331	213	....	....	20·0*	15·3*	....	" 198 "	4

* Standard reading. No reduction factor.

White Lamps. (TABLE XV.)

Lamp.	Hours of test.	Life of lamp.	Candles in efficiency tests. Spher'l.	Candles in efficiency tests. Horiz'l.	Candles. Spher.	Candles. Horizontal.	Candles.	Discoloration.
1	312	Survived.	10·8	13·1	15·9	19·2	After 253 hrs.	3½
2	312	"	11·0	13·2	14·3	17·2	" 252 "	2½
3	312	"	9·1	11·1	12·1	14·8	" 252 "	3
4	311	"	14·2	17·2	14·6	17·7	" 252 "	3
5	311	"	14·3	17·1	12·1	14·4	" 252 "	4
6	311	229	14·6	17·6	15·4	18·5	" 227 "	4
7	311	160	14·0	17·0	15·7	19·0	" 182 "	3½
8	311	Survived.	11·7	14·2	13·2	16·1	" 250 "	3
9	311	165	13·2	15·9	15·6	18·7	" 182 "	2½
10	310	Survived.	11·6	14·3	11·3	13·9	" 250 "	3

Weston Lamps, 110½ Volts. (TABLE XVI.)

Lamp.	Hours of test.	Life of lamp.	Candles in efficiency tests. Spher'l.	Candles in efficiency tests. Horiz'l.	Candles. Spher.	Candles. Horizontal.	Candles.	Discoloration.
1	1,065	227	16·6	18·4	10·8	11·9	After 198 hrs.	2½
2	1,065	47	13·8	14·9	......	......	......	½
3	1,065	Survived.	13·4	14·8	7·1	7·8	After 1,006 hrs.	2
3	1,065	107	11·7	12·7	3·8	4·2	" 77 "	1½
5	1,065	320	15·0	16·4	10·4	11·4	" 289 "	2½
6	1,065	Survived.	10·4	11·2	10·0	10·8	" 1,006 "	2
7	1,065	"	17·3	19·0	2·9	3·2	" 1,006 "	2
8	1,065	141	19·2	21·4	10·0	11·1	" 141 "	2½
9	1,065	Survived.	15·6	17·0	6·5	7·1	" 1,006 "	2
10	1,065	823	18·2	19·7	10·0	10·9	" 789 "	2
11	1,065	169	15·4	17·0	2·8	3·1	" 148 "	1½
12	1,065	81	21·3	23·3	13·9	15·3	" 76 "	2
13	1,065	256	15·4	17·0	6·0	6·6	" 241 "	2
14	1,065	213	18·3	20·4	2·6	2·9	" 196 "	1
15	1,065	193	8·9	9·4	5·5	5·9	" 193 "	1
16	1,065	Survived.	14·2	15·4	9·1	10 0	" 1.006 "	3
17	1,065	41	11·3	13·1	......	......	......	½
18	1,065	Survived.	15·8	17·0	4·4	4·7	" 1,006 "	2
19	1,065	65	19·4	21·9	10·7	12·1	" 52 "	2
20	1,065	Survived.	18·5	19·9	9·5	10·2	" 1,006 "	2

Weston Lamps, 70 Volts. (TABLE XVII.)

Lamp.	Hours of test.	Life of lamp.	Candles in efficiency tests. Spher'l.	Candles in efficiency tests. Horiz'l.	Candles. Spher.	Candles. Horizontal.	Candles.	Discoloration.
51	524	260	14·3	16·0	7·7	8·6	After 249 hrs.	2½
54	524	Survived.	14·0	15·2	13·1	14·4	" 465 "	2
55	524	"	16·7	18·3	14·8	16·3	" 465 "	2
56	524	"	14·7	16·4	13·9	15·7	" 465 "	2
58	524	"	16·3	17·9	13·3	14·6	" 465 "	2½
59	524	223	15·6	17·6	14·9	16·8	" 176 "	2½
61	524	Survived.	12·7	13·8	12·5	13·7	" 464 "	2
62	524	"	13·9	15·4	9·9	10·9	" 464 "	2
63	523	"	14·3	16·3	14·0	16·0	" 463 "	1½
64	523	463	14·8	16·1	14·0	15·4	" 462 "	2

EDISON LAMPS.

Edison Lamp, No. 1, 99 Volts.

(Reduction Factor, ·96. Resistance Cold, 260.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	98·9	·690	68·24	15·90	15·31	4·45	18·81	143·3	1·45	1·45
11	...	...	...	15·5	14·9	...	18·3	...	3·45	5·30
12	...	...	...	...	...	...	...	...	24·00	29·30
13	97·1	·664	64·48	12·3	11·8	...	14·5	146·2	24·00	53·30
14	99·0	...	...	...	...	...	...	...	24·00	77·30
15	98·0	·663	64·97	14·1	13·5	...	16·6	147·8	24·00	101·30
16	98·9	...	...	...	...	...	...	...	24·00	125·30
17	99·0	·675	66·83	13·7	13·2	...	16·2	146·7	24·00	149·30
18	100·2	·679	68·04	15·1	14·5	...	17·3	147·6	24·00	173·30
19	99·5	...	...	...	...	...	...	...	24·00	197·30
20	98·1	·655	64·26	12·4	11·9	...	14·6	149·6	20·45	218·15
21	99·7	...	...	...	...	...	...	...	24·00	242·15
22	98·6	·662	65·27	13·1	12·6	...	15·5	148·9	24·00	266·15
23	99·0	...	...	...	...	...	...	...	24·00	290·15
24	99·0	·660	65·34	12·3	11·8	...	14·5	150·0	24·00	314·15
*25	99·4	·665	66·10	10·4	10·0	...	12·3	149·5	24·00	338·15
26	99·0	...	...	...	...	...	...	...	21·00	359·15
*27	98·8	·659	65·11	10·0	9·6	...	11·8	149·9	24·00	383·15
*28	99·0	·657	65·04	10·0	9·6	...	11·8	150·7	24·00	407·15
*29	99·3	·658	65·34	9·6	9·2	...	11·3	150·9	24·00	431·15
30	98·7	·655	64·64	11·9	11·4	...	14·0	150·7	24·00	455·15
May										
1	99·1	·655	64·91	11·9	11·4	...	14·0	151·8	24·00	479·15
2	98·9	·656	64·87	11·7	11·2	...	13·8	150·8	24·00	503·15
3	98·9	...	...	...	...	...	...	...	24·00	527·15
4	99·0	...	...	...	...	...	...	...	24·00	551·15
5	99·2	·655	64·97	12·0	11·5	...	14·1	151·5	24·00	575·15
6	98·9	·647	63·98	10·7	10·3	...	12·7	152·9	23·30	598·45
7	98·8	...	...	...	...	...	...	...	24·00	622·45
8	98·8	·649	64·12	11·3	10·8	...	13·3	152·2	24·00	646·45
9	99·0	·646	63·95	11·6	11·1	...	13·3	153·3	24·00	670·45
10	98·9	...	...	...	...	...	...	...	24·00	694·45
11	98·9	·648	64·08	10·9	10·5	...	12·9	152·6	24·00	718·45
12	98·8	...	...	...	...	...	...	...	24·00	742·45
13	99·2	...	...	...	...	...	...	...	23·30	766·15
14	99·2	·646	64·08	10·5	10·1	...	12·4	153·6	24·00	790·15
15	99·0	...	...	...	...	...	...	...	24·00	814·15
16	98·6	·645	63·59	11·4	10·9	...	13·4	152·9	24·00	838·15
17	99·1	...	...	...	...	...	...	...	24·00	862·15
18	98·9	·642	63·49	11·3	10·8	...	13·3	154·1	24·00	886·15
19	98·8	·641	63·33	9·3	8·9	...	10·9	154·1	24·00	910·15
20	99·0	...	...	...	...	...	...	...	24·00	934·15
21	99·0	·639	63·26	10·5	10·1	...	12·4	154·9	24·00	958·15
22	99·1	...	...	...	...	...	...	...	24·00	982·15
23	98·7	·637	62·87	9·5	9·1	...	11·2	154·9	24·00	1,006·15
24	98·9	...	...	...	...	...	...	...	24·00	1,030·15
*25	98·8	·639	63·13	7·3	7·0	...	8·6	154·6	24·00	1,054·15
26	...	...	...	...	...	...	...	...	11·00	1,065·45
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 281. Discoloration, 3.

Edison Lamp, No. 2, 98 Volts.

(Reduction Factor, 1·03. Resistance Cold, 252.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	98·9	·703	69·44	13·95	14 38	4·83	17·62	140·7	1·00	1·00
11	…	…	…	16·0	16·5	…	20·3	…	3·45	4·45
12	…	…	…	…	…	…	…	…	24·00	28·45
13	96·3	·647	62·31	10·1	10·4	…	12·8	148·8	24·00	52·45
14	98·3	…	…	…	…	…	…	…	24·00	76·45
15	97·2	·661	64·25	12·2	12·6	…	15·5	147·1	24·00	100·45
16	98·8	…	…	…	…	…	…	…	24 00	124·45
17	98·6	·668	65·86	12·3	12·7	…	15·6	147·6	24·00	148·45
18	97·8	·666	65·13	11·9	12·3	…	15·1	146·8	24·00	172·45
19	98·6	…	…	…	…	…	…	…	24·00	196·45
20	97·6	·660	64·41	11·3	11·6	…	14·3	147·9	20·45	217·30
21	98·8	…	…	…	…	…	…	…	24·00	241·30
22	97·7	·660	64·48	11·1	11·4	…	14·0	148·0	24·00	265·30
23	98·4	…	…	…	…	…	…	…	24·00	289·30
24	98·2	·654	64·22	10·7	11·0	…	13·5	150·2	24·00	313·30
*25	98·4	·661	65·34	10·0	10·3	…	12·7	148·2	24·00	337·30
26	98·1	…	…	…	…	…	…	…	21·00	358·30
*27	97·9	·656	64·22	9·2	9·5	…	11·7	149·2	24·00	382·30
*28	98·0	·657	64·38	7·9	8·1	…	10·0	149·2	24·00	406·30
*29	98·2	·658	64·61	8·9	9·2	…	11·3	149·2	24·00	430·30
30	97·8	·653	63·86	10·6	10·9	…	13·4	149·8	24·00	454·30
May.										
1	98·1	·656	64·35	10·7	11·0	…	13·5	149·5	24·00	478·30
2	97·8	·656	64·15	11·0	11 3	…	13·9	149·1	24 00	502·30
3	98·0	…	…	…	…	…	…	…	24·00	526·30
4	97·9	…	…	…	…	…	…	…	24·00	550·30
5	98·0	·657	64·38	11·3	11·6	…	14·3	149·2	24 00	574·30
6	97·8	·651	63·66	10·1	10·4	…	12·8	150·2	23·30	598·00
7	97·8	…	…	…	…	…	…	…	24·00	622·00
8	97·9	·655	64·12	11·3	11·6	…	14·3	149·5	24·00	646·00
9	98·0	·657	64·38	11·4	11·7	…	14·4	149·2	24·00	670·00
10	97·7	…	…	…	…	…	…	…	24·00	694·00
11	97·9	·653	63·92	10·6	10·9	…	13·4	149·9	24·00	718·00
12	98·0	…	…	…	…	…	…	…	24·00	742·00
13	98·5	…	…	…	…	…	…	…	23·00	765·00
14	98·0	·655	64·19	10·0	10·3	…	12·7	149·6	24 00	789·30
15	98·0	…	…	…	…	…	…	…	24·00	813·30
16	97·7	·650	63·50	10·8	11·1	…	13·7	150·3	24·00	837·30
17	98·0	…	…	…	…	…	…	…	24·00	861·30
18	97·7	·649	63·40	11·0	11·3	…	13·9	150·5	24·00	885·30
19	97·7	·648	63·31	8·7	9·0	…	11·1	150·8	24·00	909·30
20	97·9	…	…	…	…	…	…	…	24·00	933·30
21	98·0	·648	63·50	10·3	10·6	…	13·0	151·2	24·00	957·30
22	97·8	…	…	…	…	…	…	…	24·00	981·30
23	97·6	·646	63·04	9·3	9·6	…	11·8	151·1	24·00	1,005·30
24	97·9	…	…	…	…	…	…	…	24·00	1,029·30
*25	97·7	·646	63·11	7·3	7·5	…	9·2	151·2	24·00	1,053·30
26	…	…	…	…	…	…	…	…	11·30	1,065·00
28	…	…	…	…	…	…	…	…	…	…

Resistance Cold, 267. Discoloration, 2.

Edison Lamp, No. 3, 95 Volts.

(Reduction Factor, 0·91. Resistance Cold, 241.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	95·8	·711	68·12	16·32	14·87	4·58	18·03	134·7	0·30	0·30
11	......	......	......	13·3	12·1	......	14·6	......	3·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	93·5	·650	60·77	10·4	9·5	......	11·5	143·8	24·00	52·15
14	95·4	......	......	......	......	......	......	......	24·00	76·15
15	94·2	·661	62·55	12·1	11·0	......	13·3	141·9	24·00	100·15
16	97·2	......	......	......	......	......	......	......	24·00	124·15
17	95·7	·675	64·60	12·1	11·0	......	13·8	141·5	24·00	148·15
18	95·2	·668	63·59	12·0	10·9	......	13·2	142·5	24·00	172·15
19	95·9	......	......	......	......	......	......	......	24·00	196·15
20	94·5	·667	63·03	12·2	11·1	......	13·4	141·7	20·45	217·00
21	96·1	......	......	......	......	......	......	......	24·00	241·00
22	95·2	·661	62·92	11·6	10·6	......	12·8	144·0	24·00	265·00
23	95·2	......	......	......	......	......	......	......	24·00	289·00
24	95·1	·669	63·62	11·4	10·4	......	12·6	142·2	24·00	313·00
*25	95·2	·661	62·92	9·8	8·9	......	10·8	144·0	24·00	337·00
26	95·3	......	......	......	......	......	......	......	21·00	358·00
*27	95·0	·658	62·51	9·4	8·6	......	10·4	144·4	24·00	382·00
*28	94·6	·674	63·76	10·4	9·5	......	11·5	140·4	24·00	406·00
*29	94·9	·675	64·05	10·5	9·6	......	11·6	140·6	24·00	430·00
30	94·4	·671	63 34	12·4	11·3	......	13·7	140·7	24·00	454·00
May.										
1	94·7	·671	63·54	12·9	11·7	......	14·2	141·1	24·00	478·00
2	94·9	·679	64·43	12·9	11·7	......	14·2	139·8	24·00	502·00
3	94·9	......	......	......	......	......	......	......	24·00	526·00
4	95·0	......	......	......	......	......	......	......	24·00	550·00
5	95·0	·674	64·03	13·2	12·0	......	14·5	140·9	24·00	574·00
6	94·8	·673	63·80	11·7	10·6	......	12·8	140·9	23·30	597·00
7	94·8	......	......	......	......	......	......	......	24·00	621·30
8	94·8	·669	63·42	13·2	12·0	......	14·5	141·7	24·00	645·30
9	95·0	·670	63·63	12·5	11·4	......	13·8	141·8	24·00	669·30
10	94·8	......	......	......	......	......	......	......	24·00	693·30
11	95·0	·670	63·64	12·0	10·9	......	13·2	141·8	24·00	717·30
12	94·9	......	......	......	......	......	......	......	24·00	741·30
13	95·0	......	......	......	......	......	......	......	23·30	765·00
14	95·0	·670	63·64	11·3	10·3	......	12·5	141·8	24·00	789·00
15	95·2	......	......	......	......	......	......	......	24·00	813·00
16	94·8	·667	63·23	12·0	10·9	......	13·2	142·1	24·00	837·00
17	95·2	......	......	......	......	......	......	......	24·00	861·00
18	95·0	·665	63·17	12·6	11·5	......	13·9	142·9	24·00	885·00
19	94·8	·664	62·94	10·5	9·6	......	11·6	142·8	24·00	909·00
20	94·9	......	......	......	......	......	......	......	24·00	933·00
21	94·9	·664	63·01	11·6	10·6	......	12·8	142·9	24·00	957·00
22	95·2	......	......	......	......	......	......	......	24·00	981·00
23	94·8	·661	62·66	10·5	9·6	......	11·6	143·4	24·00	1,005·00
24	94·9	......	......	......	......	......	......	......	24·00	1,029·00
*25	94·8	·662	62·75	8·3	7·6	......	9·2	143·2	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11·30	1,064·30
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold, 257. Discoloration, 2.

Edison Lamp, No. 4, 95 Volts.

(Reduction Factor, 0·93. Resistance Cold, 244.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	95·8	·718	68·79	16·90	15·72	4·37	19·44	133·4	0·30	0·30
11	......	......	......	17·4	16·2	......	20·1	......	8·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	93·3	·676	63·07	13·6	12·7	......	15·7	138·0	24·00	52·15
14	95·2	......	......	......	......	......	......	......	24·00	76·15
15	93·7	·682	63·91	15·2	14·1	......	17·5	137·4	24·00	100·15
16	97·2	......	......	......	......	......	......	......	24·00	124·15
17	95·5	·692	66·09	14·5	13·5	......	16·7	138·0	24·00	148·15
18	95·3	·690	65 96	14·5	13·5	......	16·7	138·6	24·00	172·15
19	95·8	......	......	......	......	......	......	......	24·00	196·15
20	96·0	·693	66·53	15·6	14·5	......	18·0	138·5	20·45	217·00
21	96·2	......	......	......	......	......	......	......	24·00	241·00
22	95·1	·678	64·47	13·7	12·7	......	15·7	140·3	24·00	265·00
23	95·3	......	......	......	......	......	......	......	24·00	289·00
24	95·2	·677	64·45	12·8	11·9	......	14·8	140·6	24·00	313·00
*25	95·2	·673	64·07	11·7	10·9	......	13·5	141·5	24·00	337·00
26	95·2	......	......	......	......	......	......	......	21·00	358·00
*27	94·8	·671	63·61	11·2	10·4	......	12·9	141·3	24·00	382·00
*28	95·0	·670	63·65	10·1	9·4	......	11·7	141·8	24·00	406·00
*.9	95·2	·672	63·97	10·2	9·5	......	11·8	141·7	24·00	430·00
30	95·3	·674	64·23	13·1	12·2	......	15·1	141·4	24·00	454·00
May.										
1	95·2	·673	64·07	12·6	11·7	......	14·5	141·5	24 00	478·00
2	95·0	·670	63 64	12·4	11·5	......	14·8	141·8	24·00	502·00
3	95·1	......	......	......	......	......	......	......	24·00	526·00
4	95·0	......	......	......	......	......	......	......	24·00	550·00
5	95·1	·668	63·52	13·2	12·3	......	15·3	142·4	24·00	574·00
6	95·2	·668	63·59	11·7	10·9	......	13·5	142·5	23·30	597·30
7	94·8	......	......	......	......	......	14·4	......	24·00	621·30
8	95·0	·665	63·17	12·5	11·6	......	14·4	142·9	24·00	645·30
9	95·2	·665	63·31	12·5	11·6	......	......	143·2	24·00	669·30
10	94·8	......	......	......	......	......	......	......	24·00	693·30
11	95·0	·664	63·08	11·7	10·9	......	13·5	143·1	24·00	717·30
12	94·9	......	......	......	......	......	......	......	24·00	741·30
13	95·5	......	......	......	......	......	......	......	23·30	765·00
14	95·1	·659	62·67	10·7	10·0	......	12·4	144·3	24·00	789·00
15	95·3	......	......	......	......	......	......	......	24 00	813·00
16	94·9	·660	62·63	11·6	10·8	......	13·4	143·8	24·00	837·00
17	95·3	......	......	......	......	......	......	......	24·00	861·00
18	95·2	·659	62·73	11·3	10·5	......	13·0	144·5	24·00	885·00
19	94·8	·658	62·37	9·9	9·2	......	11·4	144·1	24·00	909·00
20	95·0	......	......	......	......	......	......	......	24·00	933·00
21	95·2	·658	62·64	11·2	10·4	......	12·9	144·7	24·00	957·00
22	95·5	......	......	......	......	......	......	......	24·00	981·00
23	94·8	·653	61·90	10·2	9·5	......	11·8	145·2	24·00	1,005·00
24	94·8	......	......	......	......	......	......	......	24·00	1,029·00
*25	95·0	·656	62·31	8 1	7·5	......	9·3	144·8	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11·30	1,064·30
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold, 264. Discoloration, 2½.

Edison Lamp, No. 5, 97 Volts.

(Reduction Factor, 0·95. Resistance Cold, 244.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts, per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total hours.
1885. April.	97·8	·718	70·21	17·82	16·41	4·27	20·23	136·2	0·30	0·30
11	......	......	......	18·4	17·5	......	21·7	......	3·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	95·2	·685	65·22	14·4	13·7	......	17·0	139·0	24·00	52·15
14	97·0	......	......	......	......	......	......	......	24·00	76·15
15	95·6	·682	65·20	15·9	15·1	......	18·7	140·2	24·00	100·15
16	98·7	......	......	......	......	......	......	......	24·00	124·15
17	97·2	·699	67·94	16·9	16·0	......	19·8	139·1	24·00	148·15
18	96·5	·691	66·69	15·8	14·5	......	18·0	139·7	24·00	172·15
19	97·3	......	......	......	......	......	......	......	24·00	196·15
20	98·5	·691	68·07	15·1	14·3	......	17·7	142·5	20·45	217·00
21	98·0	......	......	......	......	......	......	......	24·00	241·00
22	96·5	·687	66·30	15·0	14·3	......	17·7	140·5	24·00	265·00
23	97·7	......	......	......	......	......	......	......	24·00	289·00
24	97·2	·669	65·03	12·3	11·7	......	14·5	145·3	24·00	313·00
*25	97·4	·670	65·25	11·3	10·7	......	13·8	145·4	24·00	337·00
26	97·0	......	......	......	......	......	......	......	21·00	358·00
*27	96·6	·684	66·07	11·9	11·3	......	14·0	141·2	24·00	382·00
*28	97·2	·664	64·54	10·1	9·6	......	11·9	146·4	24·00	406·00
*29	97·8	·670	65·19	10·2	9·7	......	12·0	145·2	24·00	430·00
30	97·1	·675	65·54	13·8	12·6	......	15·6	143·9	24·00	454·00
May.										
1	97·4	·661	64·38	11·5	10·9	......	13·5	147·4	24·00	478·00
2	97·2	·664	64·54	11·4	10·8	......	13·4	146·4	24·00	502·00
3	97·2	......	......	......	......	......	......	......	24·00	526·00
4	97·1	......	......	......	......	......	......	......	24·00	550·00
5	97·3	·662	64·41	12·6	12·0	......	14·9	147·0	24·00	574·00
6	97·2	·662	64·34	11·5	10·9	......	13·5	146·8	23·30	597·30
7	97·0	......	......	......	......	......	......	......	24·00	621·30
8	97·3	·660	64·21	11·9	11·3	......	14·0	147·4	24·00	645·30
9	97·5	·658	64·16	11·4	10·8	......	13·4	148·2	24·00	669·30
10	97·2	......	......	......	......	......	......	......	24·00	693·30
11	97·1	·658	63·89	11·1	10·5	......	13·0	147·6	24·00	717·30
12	97·4	......	......	......	......	......	......	......	24·00	741·30
13	97·1	......	......	......	......	......	......	......	23·30	765·00
14	96·9	·655	63·46	10·0	9·5	......	11·8	147·9	24·00	789·00
15	97·0	......	......	......	......	......	......	......	24·00	813·00
16	96·7	·655	63·33	11·2	10·6	......	13·1	147·6	24·00	837·00
17	96·8	......	......	......	......	......	......	......	24·00	861·00
18	96·3	·670	64·52	13·5	12·8	......	15·9	143·7	24·00	885·00
19	96·9	·665	64·43	10·6	10·1	......	12·5	145·7	24·00	909·00
20	97·0	......	......	......	......	......	......	......	24·00	933·00
21	97·4	·658	64·09	11·5	10·9	......	13·5	148·0	24·00	957·00
22	97·5	......	......	......	......	......	......	......	24·00	981·00
23	96·7	·665	64·30	10·8	10·3	......	12·8	145·5	24·00	1,005·00
24	97·0	......	......	......	......	......	......	......	24·00	1,029·00
*25	97·1	·658	63·89	8·1	7·7	......	9·5	147·6	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11·30	1,064·30
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold, 260. Discoloration, 2½.

Edison Lamp, No. 6, 99 Volts.

(Reduction Factor, 0·91. Resistance Cold, 264.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Candles.	Candles. Mean Horizontal.	Resistance Hot.	Hours	Total Hours.
1885. April.	99·9	·692	69·13	16·07	14·67	4·71	17·98	144·4	0·30	0·30
11	...	...	...	18·6	16·9	...	20·8	...	3·45	4·15
12	...	...	...	...	...	...	...	...	24·00	28·15
13	97·8	·669	65·42	14·9	13·5	...	16·6	146·2	24·00	52·15
14	99·0	...	...	...	...	...	...	...	24·00	76·15
15	97·7	·659	64·38	15·8	14·4	...	17·7	148·3	24·00	100·15
16	100·8	...	...	...	...	...	...	...	24·00	124·15
17	99·6	·674	67·13	16·0	14·6	...	18·0	147·8	24·00	148·15
18	99·1	·670	66·40	16·2	14·7	...	18·1	147·9	24·00	172·15
19	99·2	...	...	...	...	...	...	...	24·00	196·15
20	99·8	·677	67·56	15·4	14·0	...	17·2	147·4	20·45	217·00
21	99·6	...	...	...	...	...	...	...	24·00	241·00
22	98·9	·664	65·66	15·4	14·0	...	17·2	148·9	24·00	265·00
23	99·1	...	...	...	...	...	...	...	24·00	289·00
24	99·1	·661	65·50	13·1	11·9	...	14·6	149·9	24·00	313·00
*25	99·2	·660	65·47	13·0	11·8	...	15·5	150·3	24·00	337·00
26	99·0	...	...	...	...	...	...	...	21·00	358·00
*27	99·1	·660	65·40	12·0	10·9	...	13·4	150·2	24·00	382·00
*28	99·0	·659	65·24	11·1	10·1	...	12·4	150·2	24·00	406·00
*29	99·0	·659	65·24	11·2	10·2	...	12·5	150·2	24·00	430·00
30	99·1	·658	65·20	13·8	12·6	...	15·5	150·6	24·00	454·00
May.										
1	99·2	·658	65·27	14·0	12·7	...	15·6	150·8	24·00	478·00
2	98·9	·655	64·78	13·2	12·0	...	14·8	151·0	24·00	502·00
3	99·0	...	...	...	...	...	...	...	24·00	526·00
4	98·9	...	...	...	...	...	...	...	24·00	550·00
5	98·9	·652	64·48	14·0	12·7	...	15·6	151·7	24·00	574·00
6	99·2	·650	64·47	12·8	11·6	...	14·3	152·6	23·30	597·30
7	98·8	...	...	...	...	...	...	...	24·00	621·30
8	98·9	·650	64·28	13·6	12·4	...	15·3	152·2	24·00	645·30
9	99·1	·650	64·41	13·3	12·1	...	14·9	152·5	24·00	669·30
10	98·9	...	...	...	...	...	...	...	24·00	693·30
11	98·9	·650	64·28	12·7	11·6	...	14·3	152·2	24·00	717·30
12	99·1	...	...	...	...	...	...	...	24·00	741·30
13	99·1	...	...	...	...	...	...	...	23·30	765·00
14	99·0	·647	64·05	11·6	10·6	...	13·0	153·0	24·00	789·00
15	99·0	...	...	...	...	...	...	...	24·00	813·00
16	98·8	·645	63·72	12·7	11·6	...	14·3	153·2	24·00	837·00
17	98·1	...	...	...	...	...	...	...	24·00	861·00
18	98·9	·646	63·89	13·4	12·2	...	15·0	153·1	24·00	885·00
19	99·0	·645	63·85	11·4	10·4	...	12·8	153·5	24·00	909·00
20	98·1	...	...	...	...	...	...	...	24·00	933·00
21	98·8	·642	63·43	12·6	11·5	...	14·1	153·9	24·00	957·00
22	99·0	...	...	...	...	...	...	...	24·00	981·00
23	98·8	·641	63·33	11·1	10·1	...	12·4	154·1	24·00	1,005·00
24	99·0	...	...	...	...	...	...	...	24·00	1,029·00
*25	99·1	·642	63·62	8·5	7·7	...	9·5	154·4	24·00	1,053·00
26	...	...	...	...	...	...	...	...	11·30	1,064·30
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 279. **Discoloration, 2½.**

Edison Lamp, No. 7, 95 Volts.

(Reduction Factor, 0·88. Resistance Cold, 235.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	95·8	·736	70·31	16·50	14·57	4·82	18·43	130·2	0·45	0·45
11				16·8	14·8		18·6		3·45	4·30
12									24·00	28·30
13	93·8	·699	65·57	12·9	11·4		14·4	134·2	24·00	52·30
14	95·1								24·00	76·30
15	94·2	·692	65·19	14·4	12·7		16·0	136·1	24·00	100·30
16	96·7								24·00	124·30
17	95·8	·709	67·92	14·2	12·5		15·8	135·1	24·00	148·30
18	95·6	·703	67·21	15·1	13·3		16·8	136·0	24·00	172·30
19	95·4								24·00	196·30
20	94·5	·699	66·05	13·7	12·1		15·2	135·2	20·45	217·15
21	95·2								24·00	241·15
22	95·0	·695	66·03	13·7	12·1		15·2	136·7	24·00	265·15
23	95·1								24·00	289·15
24	94·9	·698	66·24	11·6	10·2		12·9	136·0	24·00	313·15
*25	95·2	·700	66·64	12·2	10·7		13·5	136·0	24·00	337·15
26	95·1								21·00	358·15
*27	95·1	·695	66·09	11·4	10·0		12·6	136·8	24·00	382·15
*28	95·0	·685	65·07	10·5	9·2		11·6	138·7	24·00	406·15
*29	95·1	·691	65·71	10·2	9·0		11·3	137·6	24·00	430·15
30	95·2	·693	65·97	13·0	11·4		14·4	137·4	24·00	454·15
May.										
1	95·0	·691	65·64	12·1	10·6		13·4	137·5	24·00	478·15
2	95·0	·690	65·55	12·9	11·4		14·4	137·7	24·00	502·15
3	94·9								24·00	526·15
4	95·1								24·00	550·15
5	94·9	·688	65·29	13·4	11·8		14·9	137·9	24·00	574·15
6	95·1	·688	65·42	12·1	10·6		13·4	138·2	23·30	597·45
7	94·9								24·00	621·45
8	95·1	·687	65·33	12·8	11·3		14·2	138·4	24·00	645·45
9	95·1	·686	65·24	12·1	10·6		13·4	138·6	24·00	669·45
10	94·9								24·00	693·45
11	95·0	·686	65·16	12·0	10·6		13·4	138·5	24·00	717·45
12	94·9								24·00	741·45
13	95·1								23·30	765·15
14	95·1	·684	65·04	11·1	9·8		12·3	139·0	24·00	789·15
15	95·0								24·00	813·15
16	94·8	·683	64·74	11·7	10·3		13·0	138·8	24·00	837·15
17	95·3								24·00	861·15
18	94·9	·681	64·62	12·2	10·7		13·5	139·4	24·00	885·15
19	95·0	·682	64·78	10·5	9·2		11·6	139·3	24·00	909·15
20	94·9								24·00	933·15
21	95·0	·678	64·41	11·5	10·1		12·7	140·1	24·00	957·15
22	94·9								24·00	981·15
23	94·9	·676	64·15	10·4	9·2		11·6	140·3	24·00	1,005·15
24	95·0								24·00	1,029·15
*25	95·1	·678	64·47	8·2	7·2		9·1	140·3	24·00	1,053·15
26									11·30	1,064·45
28										

Resistance Cold, 249. Discoloration, 2½.

Edison Lamp, No. 8, 97 Volts.

(Reduction Factor, 0·84. Resistance Cold, 239.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	97·9	·729	71·37	19·97	16·81	4·24	20·32	134·3	0·45	0·45
11	......	......	......	20·0	16·8	......	20·3	......	3·45	4·30
12	......	......	......	......	......	......	......	......	24·00	28·30
13	95·9	·696	66·75	17·0	14·3	......	17·3	137·8	24·00	52·30
14	96·9	......	......	......	......	......	......	......	24·00	76·30
15	95·9	·699	67·03	18·3	15·4	......	18·6	137·2	24·00	100·30
16	98·4	......	......	......	......	......	......	......	24·00	124·30
17	97·2	·712	69·20	18·7	15·7	......	19·0	136·5	24·00	148·30
18	97·2	·703	68·33	17·7	14·9	......	18·0	138·3	24·00	172·30
19	97·5	......	......	......	......	......	......	......	24·00	196·30
20	96·5	·699	67·45	17·1	14·4	......	17·4	138·1	20·45	217·15
21	97·0	......	......	......	......	......	......	......	24·00	241·15
22	96·8	·697	67·47	16·2	13·6	......	16·5	138·9	24·00	265·15
23	97·2	......	......	......	......	......	......	......	24·00	289·15
24	96·8	·694	67·18	14·1	11·8	......	14·3	139·5	24·00	313·15
*25	97·0	·695	67·41	14·1	11·8	......	14·3	139·6	24·00	337·15
26	97·1	......	......	......	......	......	......	......	21·00	358·15
*27	97·1	·698	67·29	13·2	11·1	......	13·4	140·1	24·00	382·15
*28	97·1	·692	67·19	12·1	10·2	......	12·3	140·3	24·00	406·15
*29	97·2	·691	67·16	11·9	10·0	......	12·1	140·7	24·00	430·15
30	97·0	·692	67·12	15·1	12·7	......	15·4	140·2	24·00	454·15
May.										
1	97·1	·690	67·00	14·3	12·0	......	14·5	140·7	24·00	478·15
2	96·8	·689	66·69	14·9	12·5	......	15·1	140·5	24·00	502·15
3	97·0	......	......	......	......	......	......	......	24·00	526·15
4	97·1	......	......	......	......	......	......	......	24·00	550·15
5	97·0	·686	66·54	15·1	12·7	......	15·4	141·4	24·00	574·15
6	97·0	·684	66·34	13·5	11·3	......	13·7	141·8	23·30	597·45
7	96·8	......	......	......	......	......	......	......	24·00	621·45
8	97·0	·682	66·15	14·6	12·3	......	14·9	142·2	24·00	645·45
9	97·1	·682	66·22	14·3	12·0	......	14·5	142·4	24·00	669·45
10	96·9	......	......	......	......	......	......	......	24·00	693·45
11	96·9	·682	66·08	13·5	11·3	......	13·7	142·1	24·00	717·45
12	97·0	......	......	......	......	......	......	......	24·00	741·45
13	97·2	......	......	......	......	......	......	......	23·30	765·15
14	97·1	·678	65·83	12·4	10·4	......	12·6	143·2	24·00	789·15
15	97·1	......	......	......	......	......	......	......	24·00	813·15
16	97·0	·680	65·96	13·9	11·7	......	14·2	142·6	24·00	837·15
17	97·2	......	......	......	......	......	......	......	24·00	861·15
18	97·2	·678	65·90	13·7	11·5	......	13·9	143·4	24·00	885·15
19	97·0	·677	65·66	11·7	9·8	......	11·9	143·3	24·00	909·15
20	97·1	......	......	......	......	......	......	......	24·00	933·15
21	97·0	·674	65·37	12·8	10·8	......	13·1	143·9	24·00	957·15
22	97·0	......	......	......	......	......	......	......	24·00	981·15
23	96·8	·671	64·95	11·8	9·9	......	12·0	144·3	24·00	1,005·15
24	96·9	......	......	......	......	......	......	......	24·00	1,029·15
*25	97·0	·674	65·37	9·4	7·9	......	9·6	143·9	24·00	1,053·15
26	......	......	......	......	......	......	......	......	11·30	1,064·45
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold, 259. Discoloration, 3.

Edison Lamp, No. 9, 95 Volts.

(Reduction Factor, 1·00. Resistance Cold, 240.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	95·8	·718	68·79	15·1	15·11	4·55	18·51	133·4	0·30	0·30
11	...	...	...	15·5	15·5	...	19·1	...	3. 45	4·15
12	...	...	...	...	...	...	...	...	24·00	28·15
13	94·2	·686	64·62	13·2	13·2	...	16·2	137·3	24·00	52·15
14	95·0	...	...	...	...	...	...	...	24·00	76·15
15	94·3	·691	65·16	1·43	14·3	...	17·6	136·5	24·00	100·15
16	96·7	...	...	...	...	...	...	...	24·00	124·15
17	94·7	·696	65·91	13·8	13·8	...	17·0	136·1	24·00	148·15
18	94·6	·692	65·46	14·3	14·3	...	17·6	136·7	24·00	172·15
19	95·9	...	...	...	...	...	...	...	24·00	196·15
20	94·0	·686	64·48	12·1	12·1	...	14·9	137·0	20·45	217·00
21	95·3	...	...	...	...	...	...	...	24·00	241·00
22	94·8	·688	65·22	12·9	12·9	...	15·9	137·8	24·00	265·00
23	95·3	...	...	...	...	...	...	...	24·00	289·00
24	95·1	·690	65·62	11·1	11·1	...	13·7	137·8	24·00	313·00
*25	95·2	·687	65·40	11·0	11·0	...	13·5	138·6	24·00	337·00
26	95·1	...	...	...	...	...	...	...	21·00	358·00
*27	94·9	·682	64·72	10·4	10·4	...	12·8	139·2	24·00	382·00
*28	95·1	·681	64·76	9·7	9·7	...	11·9	139·6	24·00	406·00
*29	95·3	·684	65·18	9·5	9·5	...	11·7	139·3	24·00	430·00
30	95·1	·683	64·95	12·6	12·6	...	15·5	139·2	24·00	454·00
May.										
1	95·3	·682	64·99	12·2	12·2	...	15·0	139·7	24·00	478·00
2	95·1	·680	64·66	11·6	11·6	...	14·8	139·9	24 00	502·00
3	95·1	...	...	...	...	...	...	...	24·00	526·00
4	95·1	...	...	...	...	...	...	...	24·00	550.00
5	95·1	·678	64·47	11·8	11·8	...	14·5	140·3	24·00	574·00
6	94·9	·674	63·96	11·4	11·4	...	14·0	140·8	23·30	597·30
7	95·0	...	...	...	...	...	...	...	24·00	621·30
8	95·3	·678	64·61	11·7	11·7	...	14·4	140·6	24·00	645·30
9	95·2	·676	64·36	11·7	11·7	...	14·4	140·8	24·00	669·30
10	95·1	...	...	...	...	...	...	...	24·00	693·30
11	95·0	·674	64·03	11·0	11·0	...	13·5	140·9	24·00	717·30
12	94·9	...	...	...	...	...	...	...	24·00	741·30
13	95·3	...	...	...	...	...	...	...	23·30	765·00
14	95·1	·674	64·09	9·8	9·8	...	12·1	141·1	24·00	789·00
15	95·4	...	...	...	...	...	...	...	24·00	813·00
16	95·2	·675	64·26	11·0	11·0	...	13.5	141·0	24·00	837·00
17	95·3	...	...	...	...	...	...	...	24·00	861·00
18	95·0	·668	63·46	11·0	11·0	...	13·5	142·2	24·00	885·00
19	95·0	·668	63·46	9·5	9·5	...	11·7	142·2	24·00	909·00
20	94.9	...	...	...	...	...	...	...	24·00	933·00
21	95·0	·666	63·26	10·7	10·7	...	13·2	142·6	24·00	957·00
22	95·3	...	...	...	...	...	...	...	24·00	981·00
23	94·8	·663	62·85	9·6	9·6	...	11·8	143·0	24·00	1,005·00
24	95·0	...	...	...	...	...	...	...	24·00	1,029·00
*25	95·1	·666	63·33	7·5	7·5	...	9·2	142·9	24·00	1,053·00
26	...	...	...	...	...	...	...	...	11·30	1,064·30
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 257. Discoloration, 2½.

Edison Lamp, No. 10, 97 Volts.

(Reduction Factor, 0·98. Resistance Cold, 246.)

Date.	Volts.	Amperes	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	97·8	·714	69·83	14·92	14·58	4·79	18·54	187·0	0·30	0·30
11	......	......	......	16·8	16·5	......	21·0	......	3·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	96·2	·680	66·28	12·8	12·5	......	15·9	139·6	24·00	52·15
14	97·0	......	......	......	......	......	......	......	24·00	76·15
15	96·3	·687	66·16	13·5	13·2	......	16·8	140·2	24·00	100·15
16	98·2	......	......	......	......	......	......	......	24·00	124·15
17	96·5	·688	66·40	12·8	12·6	......	16·0	140·3	24·00	148·15
18	95·7	·685	65·56	13·4	13·1	......	16·6	139·7	24·00	172·15
19	97·8	......	......	......	......	......	......	......	24·00	196·15
20	96·1	·683	65·64	12·3	12·1	......	15·4	140·7	20·45	217·00
21	97·2	......	......	......	......	......	......	......	24·00	241·00
22	96·8	·685	66·31	12·3	12·1	......	15·4	141·3	24·00	265·00
23	97·2	......	......	......	......	......	......	......	24·00	289·00
24	97·0	·683	66·25	11·7	11·5	......	14·6	142·0	24·00	313·00
*25	97·2	·685	66·58	10·9	10·7	......	13·6	141·9	24·00	337·00
26	96·8	......	......	......	......	......	......	......	21·00	358·00
*27	96·7	·681	65·85	10·5	10·3	......	13·1	142·0	24·00	382·00
*28	97·0	·683	66·25	9·6	9·4	......	11·9	142·0	24·00	406·00
*29	96·8	·682	66·01	9·6	9·4	......	11·9	141·9	24·00	430·00
80	96·7	·682	65·95	11·7	11·5	......	14·6	141·8	24·00	454·00
May.										
1	97·3	·682	66·35	12·2	12·0	......	15·2	142·7	24·00	478·00
2	97·0	·681	66·05	12·0	11·8	......	15·0	142·4	24·00	502·00
8	97·1	......	......	......	......	......	......	......	24·00	526·00
4	97·1	......	......	......	......	......	......	......	24·00	550·00
5	97·0	·682	66·15	12·0	11·8	......	15·0	142·2	24·00	574·00
6	97·1	·678	65·83	11·4	11·2	......	14·2	143·2	23·30	597·30
7	96·9	......	......	......	......	......	......	......	24·00	621·30
8	96·9	·677	65·60	11·8	11·6	......	14·7	143·1	24·00	645·30
9	97·1	·677	65·74	11·6	11·4	......	14·5	143·4	24·00	669·30
10	96·9	......	......	......	......	......	......	......	24·00	693·30
11	96·9	·675	65·40	11·1	10·9	......	13·8	143·6	24·00	717·30
12	97·1	......	......	......	......	......	......	......	24·00	741·30
13	97·3	......	......	......	......	......	......	......	23·30	765·00
14	97·2	·676	65·70	10·3	10·0	......	12·7	143·8	24·00	789·00
15	97·1	......	......	......	......	......	......	......	24·00	813·00
16	97·2	·675	65·61	11·2	11·0	......	14·0	144·0	24·00	837·00
17	87·3	......	......	......	......	......	......	......	24·00	861·00
18	97·2	·674	65·51	11·5	11·3	......	14·4	144·2	24·00	885·00
19	97·1	·672	65·25	10·2	10·0	......	12·7	144·5	24·00	909·00
20	97·0	......	......	......	......	......	......	......	24·00	933·00
21	97·0	·669	64·89	10·8	10·6	......	13·5	145·0	24·00	957·00
22	97·6	......	......	......	......	......	......	......	24·00	981·00
23	96·6	·664	61·14	9·7	9·5	......	12·1	145·5	24·00	1,005·00
24	96·8	......	......	......	......	......	......	......	24·00	1,029·00
*25	96·9	·667	64·63	7·5	7·4	......	9·4	145·3	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11.30	1,064·30
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold, 259. Discoloration, 2.

Edison Lamp, No. 11, 98 Volts.

(Reduction Factor, 0·91. Resistance Cold, 250.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885 April.	98·7	·711	70·18	18·25	16·66	4·21	20·98	138·8	0·45	0·45
11	...	...	...	16·6	15·1	...	19·0	...	3·45	4·30
12	...	...	...	...	...	...	...	...	24·00	28·30
13	97·5	·692	67·47	14·5	13·2	...	16·5	140·9	24·00	52·30
14	98·3	...	...	...	...	...	...	...	24·00	76·30
15	97·6	·693	67·63	16·7	15·2	...	19·2	140·8	24·00	100·30
16	98·9	...	...	...	...	...	...	...	24·00	124·30
17	97·7	·689	67·41	14·8	13·5	...	17·0	141·6	24·00	148·30
18	97·8	·687	67·19	16·6	15·1	...	19·0	142·4	24·00	172·30
19	99·6	...	...	...	...	...	...	...	24·00	196·30
20	97·0	·689	65·96	14·5	13·2	...	16·6	142·6	20·45	217·15
21	97·7	...	...	...	...	...	...	...	24·00	241·15
22	97·8	·689	66·50	14·5	13·2	...	16·6	143·8	24·00	265·15
23	97·9	...	...	...	...	...	...	...	24·00	289·15
23	97·5	·675	65·81	12·5	11·4	...	14·4	144·4	24·00	313·15
*25	98·0	·674	66·05	11·5	10·5	...	13·2	145·4	24·00	337·15
26	98·0	...	...	...	...	...	...	...	21·00	358·15
*27	97·6	·672	65·58	11·8	10·7	...	13·5	145·2	24·00	382·15
*28	97·8	·673	65·82	10·6	9·6	...	12·1	145·3	24·00	406·15
*29	97·8	·667	65·23	10·1	9·2	...	11·6	146·6	24·00	430·15
30	97·6	·673	65·68	13·2	12·0	...	15·5	145·0	24.00	454·15
May,										
1	97·5	·667	65·03	13·1	11·9	...	15·0	146·2	24·00	478·15
2	97·7	·668	65·26	12·6	11·5	...	14·5	146·3	24·00	502·15
3	98·0	...	...	...	...	...	...	...	24·00	526·15
4	98·0	...	...	...	...	...	...	...	24·00	550·15
5	97·9	·668	65·39	13·0	11·8	...	14·9	146·6	24·00	574·15
6	98·0	·666	65·26	12·1	11·0	...	13·9	147·2	23·30	597·45
7	97·6	·662	64·61	12·3	11·2	...	14·1	147·4	24·00	621·45
8	98·1	...	...	...	...	...	...	...	24·00	645·45
9	97·9	·664	65·01	12·4	11·3	...	14·2	147·4	24·00	669·45
10	97·7	...	...	...	...	...	...	...	24·00	693·45
11	97·8	·662	64·74	11·5	10·5	...	13·2	147·7	24·00	717·45
12	97·8	...	...	...	...	...	...	...	24·00	741·45
13	97·9	...	...	...	...	...	...	...	23·30	765·15
14	98·0	·662	64·87	11·5	10·5	...	13·2	148·0	24·00	789·15
15	98·0	...	...	...	...	...	...	...	24·00	813·15
16	97·6	·659	64·31	12·1	11·0	...	13·9	148·1	24·00	837·15
17	97·9	...	...	...	...	...	...	...	24·00	861·15
18	97·7	·660	64·48	12·0	10·9	...	13·7	148·0	24·00	885·15
19	97·8	·658	64·35	10·3	9·4	...	11·8	148·6	24·00	909·15
20	97·9	...	...	...	...	...	...	...	24·00	933·15
21	97·8	·656	64·15	11·4	10·4	...	13·1	149·1	24·00	957·15
22	97·9	...	...	...	...	...	...	...	24·00	981·15
23	97·6	·653	63·73	10·4	9·5	...	12·0	149·5	24·00	1,005·15
24	97·9	...	...	...	...	...	...	...	24·00	1,029·15
*25	97·9	·659	64·51	8·0	7·3	...	9·2	148·6	24·00	1,053·15
26	...	...	...	...	...	...	...	...	11·30	1,064·45
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 269. Discoloration, 8.

Edison Lamp, No. 12, 98 Volts.

(Reduction Factor, 0·93. Resistance Cold, 254.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	98·8	·686	67·77	14·72	13·76	4·92	17·48	144·0	1·00	1·00
11	......	......	......	16·4	15·3	......	19·4	......	3·45	4·45
12	......	......	......	......	......	......	......	......	24·00	28·45
13	97·2	·669	65·02	13·0	12·1	......	15·4	145·3	24·00	52·45
14	98·0	......	......	......	......	......	......	......	24·00	76·45
15	97·4	·671	65·35	14·7	13·7	......	17·4	145·2	24·00	100·45
16	96·1	......	......	......	......	......	......	......	24·00	124·45
17	97·5	·669	65·23	12·7	11·8	......	15·0	145·7	24·00	148·45
18	97·6	·671	65·49	14·7	13·7	......	17·4	145·5	24·00	172·45
19	99·5	......	......	......	......	......	......	......	24·00	196·45
20	96·9	·664	64·34	13·2	12·3	......	15·6	145·9	20·45	217·30
21	98·0	......	......	......	......	......	......	......	24·00	241·30
22	97·9	·669	65·50	12·9	12·0	......	15·2	146·3	24·00	265·30
23	98·2	......	......	......	......	......	......	......	24·00	289·30
24	97·9	·667	65·30	12·0	11·2	......	14·2	146·8	24·00	313·30
*25	98·1	·666	65·33	11·7	10·9	......	13·8	147·3	24·00	337·30
26	97·9	......	......	......	......	......	......	......	21·00	358·30
*27	97·8	·668	65·33	11·8	11·0	......	14·0	146·4	24·00	382·30
*28	98·0	·666	65·26	9·7	9·0	......	11·4	147·2	24·00	406·30
*29	97·8	·660	64·54	9·9	9·2	......	11·7	148·2	24·00	430·30
30	97·8	·664	64·94	13·0	12·1	......	15·4	147·3	24·00	454·30
May.										
1	98·0	·663	64·97	12·6	11·7	......	14·9	147·8	24·00	478·30
2	97·7	·665	64·97	12·3	11·4	......	14·5	146·9	24·00	502·30
3	97·8	......	......	......	......	......	......	......	24·00	526·30
4	97·7	......	......	......	......	......	......	......	24·00	550·30
5	97·9	·660	64·61	13·2	12·3	......	15·6	148·3	24·00	574·30
6	97·8	·658	64·35	11·4	10·6	......	13·5	148·6	23·30	598·00
7	97·6	·657	64·12	12·1	11·3	......	14·4	148·6	24·00	622·00
8	97·8	......	......	......	......	......	......	......	24·00	646·00
9	97·8	·658	64·35	12·8	11·9	......	15·1	148·6	24·00	670·00
10	97·6	......	......	......	......	......	......	......	24·00	694·00
11	97·8	·659	64·45	11·6	10·8	......	13·7	148·4	24·00	718·00
12	97·7	......	......	......	......	......	......	......	24·00	742·00
13	98·0	......	......	......	......	......	......	......	23·30	765·30
14	97·9	·656	64·22	11·1	10·3	......	13·1	149·2	24·00	789·30
15	97·9	......	......	......	......	......	......	......	24·00	813·30
16	97·7	·653	63·79	11·5	10·7	......	13·6	149·6	24·00	837·30
17	97·8	......	......	......	......	......	......	......	24·00	861·30
18	97·8	·653	63·86	11·9	11·1	......	14·1	149·8	24·00	885·30
19	97·7	·654	63·89	10·1	9·4	......	11·9	149·4	24·00	909·30
20	97·6	......	......	......	......	......	......	......	24·00	933·30
21	98·0	·653	63·99	11·5	10·7	......	13·6	150·1	24·00	957·30
22	98·1	......	......	......	......	......	......	......	24·00	981·30
23	97·6	·649	63·34	10·7	10·0	......	12·7	150·4	24·00	1,005·30
24	97·9	......	......	......	......	......	......	......	24·00	1,029·30
*25	97·8	·652	63·76	8·1	7·5	......	9·5	150·0	24·00	1,053·30
26	......	......	......	......	......	......	......	......	11·30	1,065·00
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold 268. Discoloration, 2.

Edison Lamp, No. 13, 96 Volts.

(Reduction Factor, 0·93. Resistance Hot, 235.)

Date.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
				Observed.	Spherical.					
1885. April.	96·7	·723	69·91	16·67	15·44	4·52	19·00	133·7	0·30	0·30
11	......	......	......	15·6	14·5	......	17·8	......	3·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	95·0	·700	66·50	14·0	13·0	......	16·0	135·7	24·00	52·15
14	95·9	......	......	......	......	......	......	......	24·00	76·15
15	95·4	·705	67·28	15·1	14·0	......	17·2	135·8	24·00	100·15
16	95·9	......	......	......	......	......	......	......	24·00	124·15
17	95·4	·710	67·73	14·3	13·3	......	16·4	134·4	24·00	148·15
18	95·9	·710	68·09	16·3	15·2	......	18·7	135·1	24·00	172·15
19	97·4	......	......	......	......	......	......	......	24·00	196·15
20	95·2	·705	67·12	13·4	12·5	......	15·4	135·0	20·45	217·00
21	96·1	......	......	......	......	......	......	......	24·00	241·00
22	95·9	·706	67·70	13·8	12·8	......	15·7	135·8	24·00	265·00
23	96·2	......	......	......	......	......	......	......	24·00	289·00
24	95·8	·702	67·25	12·2	11·3	......	13·9	136·5	24·00	313·00
*25	96·0	·703	67·48	11·5	10·7	......	13·2	136·6	24·00	337·00
26	95·9	......	......	......	......	......	......	......	21·00	358·00
*27	95·9	·702	67·32	11·6	10·8	......	13·3	136·6	24·00	382·00
*28	95·9	·700	67·13	10·5	9 8	......	12·1	137·0	24·00	406·00
*29	95·8	·700	67·06	10·1	9·4	......	11·6	136·9	24·00	430·00
30	95·8	·702	67·25	12·9	12·0	......	14·8	136·5	24·00	454·00
May.										
1	96·0	·698	67·00	12·5	11·6	......	14·3	137·5	24·00	478·00
2	95·8	·699	66·96	12·4	11.5	......	14·1	137·1	24·00	502·00
3	95·9	......	......	......	......	......	......	......	24·00	526·00
4	95·1	......	......	......	......	......	......	......	24·00	550·00
5	96·0	·700	67·20	12·7	11·8	......	14·5	137·1	24·00	574·00
6	96·3	·699	67·31	11·8	11·0	......	13·5	137·8	23·30	597·30
7	96·0	·696	66·81	12·3	11·4	......	14·0	137·9	24·00	621·30
8	96·2	......	......	......	......	......	......	......	24·00	645·30
9	96·2	·697	67·05	12·5	11·6	......	14·3	138·0	24·00	669·30
10	96·1	......	......	......	......	......	......	......	24·00	693·30
11	96·0	·695	66·71	11·5	10·7	......	13 2	138·1	24·00	717·30
12	96·1	......	......	......	......	......	......	......	24·00	741·30
13	96·1	......	......	......	......	......	......	......	23·30	765·00
14	96·1	·695	66·78	11·4	10·6	......	13·0	138·3	24·00	789·00
15	96·2	......	......	......	......	......	......	......	24·00	813·00
16	96·2	·693	66·66	11·6	10.8	......	13·3	138·8	24·00	837·00
17	96·1	......	......	......	......	......	......	......	24·00	861·00
18	96·2	·691	66·47	12·0	11·2	......	13·8	139·2	24·00	885·00
19	96·1	·693	66·59	9·8	9·1	......	11·2	138·7	24·00	909·00
20	96·1	......	......	......	......	......	......	......	24·00	933·00
21	96·2	·689	66·28	11·4	10·6	......	13·0	139·6	24·00	957·00
22	96·2	......	......	......	......	......	......	......	24·00	981·00
23	95·8	·687	65·81	10·6	9·9	......	12·2	139·4	24·00	1,005·00
24	96·2	......	......	......	......	......	......	......	24·00	1,029·00
*25	96·1	·[illegible]89	66·21	8·3	7·7	......	9·5	139·5	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11·30	1,064·30
28	......	......	......	......	......	......	......	......	......	......

Resistance Cold, 247. **Discoloration, 2½.**

Edison Lamp, No. 14, 96 Volts.

(Reduction Factor, 0·94. Resistance Cold, 245.)

Date.	Volts.	Amperes.	Watts.	Candles.		Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
				Observed.	Spherical.					
1885. April.	96·7	·707	68·37	16·63	15·62	4·87	19·70	136·8	0·30	0·30
11	...	...	...	17·4	16·4	...	20·7	...	3·45	4·15
12	...	...	...	...	...	...	...	...	24·00	28·15
13	95·3	·690	65·76	14·0	13·2	...	16·6	138·1	24·00	52·15
14	96·2	...	...	...	...	...	...	...	24·00	76·15
15	95·7	·696	66·61	15·2	14·3	...	18·0	137·5	24·00	100·15
16	96·3	...	...	...	...	...	...	...	24·00	124·15
17	95·9	·693	66·46	14·4	13·6	...	17·1	138·4	24·00	148·15
18	96·3	·697	67·12	15·7	14·8	...	18·6	138·2	24·00	172·15
19	97·6	...	...	...	...	...	...	...	24·00	196·15
20	95·3	·687	65·47	13·1	12·3	...	15·5	138·7	20·45	217·00
21	96·9	...	...	...	...	...	...	...	24·00	241·00
22	95·9	·685	65·69	13·1	12·3	...	15·5	140·0	24·00	265·00
23	96·3	...	...	...	...	...	...	...	24·00	289·90
24	96·1	·681	65·44	12·0	11·3	...	14·2	141·1	24·00	313·00
*25	96·2	·688	66·18	11·3	10·6	...	13·4	139·8	24·00	337·00
26	96·2	...	...	...	...	...	...	...	21·00	358·00
*27	96·0	·680	65·28	11·0	10·3	...	13·0	141·2	24·00	382·00
*28	96·2	·680	65·41	10·1	9·5	...	12·0	141·5	24·00	406·00
*29	96·3	·681	65·58	10·3	9·7	...	12 2	141·4	24·00	430·00
30	96·4	·680	65·55	12·9	12·1	...	15.2	141·8	24·00	454·00
May.										
1	96·1	·677	65·06	12·4	11·7	...	14·7	141·9	24·00	478·00
2	96·1	·679	65·25	11·9	11·2	...	14·1	141·5	24·00	502·00
3	96·1	...	...	...	...	...	...	...	24·00	526·00
4	96·1	...	...	...	...	...	...	...	24·00	550·00
5	96·1	·677	65·06	12·3	11·6	...	14·6	141·9	24·00	574·00
6	96·3	·674	64·90	11·5	10·8	...	13·6	142·9	23·30	597·30
7	96·0	·670	64·31	12·0	11·3	...	14·2	143·3	24·00	621·30
8	96·1	...	...	...	...	...	...	...	24·00	645·30
9	96·3	·671	64·62	12·3	11·6	...	14·6	143·5	24·00	669·30
10	96.3	...	...	...	...	...	...	...	24·00	693·30
11	96·0	·669	64·22	11·3	10·6	...	13·4	143·5	24·00	717·30
12	96·0	...	...	...	...	...	...	...	24·00	741·30
13	96·3	...	...	...	...	...	...	...	23·30	765·00
14	96·1	·670	64·38	10·8	10·2	...	12·9	143·4	24·00	789·00
15	96·3	...	...	...	...	...	...	...	24·00	813·00
16	96·0	·667	64·03	11·0	10·3	...	13·0	143·9	24·00	837·00
17	96·5	...	...	...	...	...	...	...	24·00	861·00
18	95·7	·663	63·44	11·1	10·4	...	13·1	144·3	24·00	885·00
19	95·7	·662	63·35	9·4	8·8	...	11·1	144·6	24·00	909·00
20	95·8	...	...	...	...	...	...	...	24·00	933·00
21	95·7	·660	63·16	10·6	10·0	...	12·6	145·0	24·00	957·00
22	96·0	...	...	...	...	...	...	...	24·00	981·00
23	95·7	·658	62·97	9·7	9·1	...	11·5	145·4	24·00	1,005·00
24	95·9	...	...	...	...	...	...	...	24·00	1,029·00
*25	95·8	·659	63·13	7·7	7·2	...	9·1	145·4	24·00	1,053·00
26	...	...	...	...	...	...	...	...	11·30	1,064·00
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 260. Discoloration, 3.

Edison Lamp, No. 15, 99 Volts.

(Reduction Factor, 1·09. Resistance Cold, 2·55.)

Date.	Volts.	Amperes.	Watts.	Candles Observed	Candles Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	99·7	·692	68·99	14·30	15·65	4·40	19·74	144·1	0·30	0·30
11	....	....	....	14·4	15·7	....	19·8	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	98·1	·662	64·94	11·2	12·3	....	15·5	148·2	24·00	52·15
14	99·1	....	....	....	....	....	....	....	24·00	76·15
15	98·5	·667	65·70	12·4	13·5	....	17·0	147·7	24·00	100·15
16	99·0	....	....	....	....	....	....	....	24·00	124·15
17	98·9	·671	66·36	11·5	12·5	....	15·8	147·4	24·00	148·15
18	98·9	·674	66·65	12·5	13·6	....	17·1	146·7	24·00	172·15
19	100·1	....	....	....	....	....	....	....	24·00	196·15
20	98·1	·666	65·34	11·2	12·2	....	15·4	147·3	20·45	217·00
21	99·8	....	....	....	....	....	....	....	24·00	241·00
22	98·8	·665	65·71	11·2	12·2	....	15·4	148·6	24·00	265·00
23	99·4	....	....	....	....	....	....	....	24·00	289·00
24	....	....	....	....	....	....	....	....	6·00	295·00

Carbon broke at side of loop 6.00 A. M., April 24, 1885. Discoloration, 2.

Edison Lamp, No. 16, 95 Volts.

(Reduction Factor, 0·79. Resistance Cold, 239.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	95·7	·714	68·33	20·30	16·09	4·24	20·26	134·0	0·30	0·30
11	...	...	...	19·0	15·0	...	18·9	...	3·45	4·15
12	...	...	...	...	...	...	...	...	24·00	28·15
13	94·1	·689	64·84	16·2	12·8	...	16·1	136·6	24·00	52·15
14	95·2	...	...	...	...	...	...	...	24·00	76·15
15	94·9	·696	66·05	17·2	13·6	...	17·1	136·4	24·00	100·15
16	95·0	...	...	...	...	...	...	...	24·00	124·15
17	95·1	·696	66·19	15·7	12·4	...	15·6	136·6	24·00	148·15
18	95·8	·699	66·96	17·1	13·5	...	17·0	137·1	24·00	172·15
19	95·9	...	...	...	...	...	...	...	24·00	196·15
20	94·2	·689	64·90	15·7	12·4	...	15·6	136·7	20·45	217·00
21	96·0	...	...	...	...	...	...	...	24·00	241·00
22	95·0	·687	65·27	15·1	11·9	...	15·0	138·3	24·00	265·00
23	95·2	...	...	...	...	...	...	...	24·00	289·00
24	95·2	·685	65·21	14·1	11·1	...	14·0	139·0	24·00	313·00
*25	95·1	·684	65·04	12·7	10·0	...	12·6	139·0	24·00	337·00
26	95·2	...	...	...	...	...	...	...	21·00	358·00
*27	95·1	·682	64·85	12·8	10·1	...	12·7	139·4	24·00	382·00
*28	95·0	·682	64·79	11·6	9·2	...	11·7	139·3	24·00	406·00
*29	95·1	·682	64·85	11·5	9·1	...	11·5	139·4	24·00	430·00
30	95·1	·684	65·04	14·6	11·5	...	14·5	139·0	24·00	454·00
May.										
1	95·0	·678	64·41	14·3	11·3	...	14·2	140·1	24·00	478·00
2	95·0	·678	64·41	13·9	11·0	...	13·9	140·1	24·00	502·00
3	95·1	...	...	...	...	...	...	...	24·00	526·00
4	95·1	...	...	...	...	...	...	...	24·00	550·00
5	95·0	·679	64·50	14·8	11·7	...	14·7	139·9	24·00	574·00
6	95·0	·677	64·31	12·9	10·2	...	12·9	140·3	23·30	597·30
7	94·9	·670	63·58	13·5	10·7	...	13·5	141·6	24·00	621·30
8	95·0	...	...	...	...	...	...	...	24·00	645·30
9	95·1	·674	64·10	13·7	10·8	...	13·6	141·1	24·00	669·30
10	94·9	...	...	...	...	...	...	...	24·00	693·30
11	94·9	·671	63·67	12·5	9·9	...	12·5	141·4	24·00	717·30
12	94·8	...	...	...	...	...	...	...	23·00	741·30
13	95·1	...	...	...	...	...	...	...	23·30	765·00
14	95·0	·671	63·74	12·1	9·6	...	12·1	141·6	24·00	789·00
15	95·3	...	...	...	...	...	...	...	24·00	813·00
16	94·9	·670	63·58	13·1	10·3	...	13·0	141·6	24·00	837·00
17	95·3	...	...	...	...	...	...	...	24·00	861·00
18	95·0	·669	63·55	12·7	10·0	...	12·6	142·0	24·00	885·00
19	94·9	·669	63·48	11·2	8·8	...	11·1	141·9	24·00	909·00
20	94·7	...	...	...	...	...	...	...	24·00	933·00
21	95·2	·667	63·50	12·0	9·5	...	12·0	142·7	24·00	957·00
22	95·1	...	...	...	...	...	...	...	24·00	981·00
23	94·7	·664	62·88	11·5	9·1	...	11·5	142·6	24·00	1,005·00
24	95·0	...	...	...	...	...	...	...	24·00	1,029·00
*25	94·8	·665	63·04	8·9	7·0	...	8·8	142·6	24·00	1,053·00
26	...	...	...	...	...	...	...	...	11·30	1,064·30
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 256. Discoloration, 2½.

Edison Lamp, No. 17, 98 Volts.

(Reduction Factor, 0·92. Resistance Cold, 259.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1882. April.	98·8	·701	69·26	17·98	16·61	4·17	21·10	140·9	1·00	1·00
11	....	....	....	16·8	15·5	....	19·7	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	96·9	·679	65·79	15·1	13·9	....	17·7	142·7	24·00	52·45
14	98·0	....	....	....	....	....	....	....	24·00	76·45
15	97·6	·682	66·56	15·3	14·1	....	17·9	143·1	24·00	100·45
16	98·0	....	....	....	....	....	....	....	24·00	124·45
17	98·0	·685	67·13	14·7	13·5	....	17·1	143·1	24·00	148·45
18	98·4	·684	67·31	15·9	14·6	....	18·5	143·9	24·00	172·45
19	99·0	....	....	....	....	....	....	....	24·00	196·45
20	98·5	·681	67·08	15·1	13·9	....	17·7	144·6	20·45	217·30
21	99·0	....	....	....	....	....	....	....	24·00	241·30
22	98·1	·675	66·22	13·7	12·6	....	16·0	145·3	24·00	265·30
23	98·4	....	....	....	....	....	....	....	24·00	289·30
24	98·3	·670	65·86	12·6	11·6	....	14·7	146·7	24·00	313·30
*25	98·5	·672	66·19	11·5	10·6	....	13·5	146·6	24·00	337·30
26	98·5	....	....	....	....	....	....	....	21·00	358·30
*27	98·4	·666	65·53	11·3	10·4	....	13·2	147·8	24·00	382·30
*28	97·8	·661	64·64	10·1	9·3	....	11·8	148·0	24·00	406·30
*29	98·0	·661	64·77	9·6	8·8	....	11·2	148·3	24·00	430·30
30	98·1	·660	64·74	12·0	11·0	....	14·0	148·6	24·00	454·30
May.										
1	98·0	·656	64·28	12·1	11·1	....	14·1	149·4	24·00	478·30
2	97·9	·655	64·12	11·5	10·6	....	13·5	149·5	24·00	502·30
3	97·9	....	....	....	....	....	....	....	24·00	526·30
4	98·1	....	....	....	....	....	....	....	24·00	550·30
5	97·8	·650	63·57	11·5	10·6	....	13·5	150·5	24·00	574·30
6	97·9	·651	63·73	10·7	9·8	....	12·4	150·4	23·30	598·00
7	97·7	·648	63·31	10·9	10·0	....	12·7	150·8	24·00	622·00
8	97·9	....	....	....	....	....	....	....	24·00	646·00
9	97·9	·648	63·44	11·7	10·8	....	13·7	151·1	24·00	670·00
10	97·8	....	....	....	....	....	....	....	24·00	694·00
11	97·7	·648	63·31	10·6	9·8	....	12·4	150·8	24·00	718·00
12	97·7	....	....	....	....	....	....	....	24·00	742·00
13	98·4	....	....	....	....	....	....	....	23·30	765·30
14	98·0	·647	63·40	10·5	9·7	....	12·3	151·5	24·00	789·30
15	97·9	....	....	....	....	....	....	....	24·00	813·30
16	97·7	·650	63·50	10·6	9·8	....	12·4	150·3	24·00	837·30
17	98·1	....	....	....	....	....	....	....	24·00	861·30
18	98·0	·644	63·11	10·8	9·9	....	12·6	152·2	24·00	885·30
19	97·8	·643	62·88	8·8	8·1	....	10·3	152·1	24·00	909·30
20	97·9	....	....	....	....	....	....	....	24·00	933·30
21	98·0	·640	62·72	10·3	9·5	....	12·1	153·1	24·00	957·30
22	98·1	....	....	....	....	....	....	....	24·00	981·30
23	97·6	·638	62·26	9·5	8·7	....	11·0	153·0	24·00	1,005·30
24	97·8	....	....	....	....	....	....	....	24·00	1,029·30
*25	97·9	·639	62·55	7·5	6·9	....	8·8	153·2	24·00	1,053·30
26	....	....	....	....	....	....	....	....	11·30	1,065·00
28	....	....	....	....	....	....	....	....	....	....

Resistance Cold, 280. Discoloration, 3.

Edison Lamp, No. 18, 97 Volts.

(Reduction Factor, 0·96. Resistance Cold, 242.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	97·7	·708	69·17	16·34	15·60	4·43	19·25	138·0	0·30	0·30
11	…	…	…	13·6	13·1	…	16·1	…	3·45	4·15
12	…	…	…	…	…	…	…	…	24·00	28·15
13	95·8	·669	64·09	11·2	10·7	…	13·2	143·2	24·00	52·15
14	97·1	…	…	…	…	…	…	…	24·00	76·15
15	96·5	·674	65·04	12·0	11·5	…	14·1	143·2	24·00	100·15
16	97·0	…	…	…	…	…	…	…	24·00	124·15
17	96·9	·681	65·99	10·9	10·5	…	12·9	142·3	24·00	148·15
18	97·5	·682	66·50	13·0	12·5	…	15·4	143·0	24·00	172·15
19	97·7	…	…	…	…	…	…	…	24·00	196·15
20	97·4	·682	66·43	12·2	11·7	…	14·4	142·8	20·45	217·00
21	97·7	…	…	…	…	…	…	…	24·00	241·00
22	96·9	·678	65·70	11·3	10·8	…	13·3	142·9	24·00	265·00
23	96·9	…	…	…	…	…	…	…	24·00	289·00
24	96·9	·671	65·02	10·0	9·6	…	11·8	144·4	24·00	313·00
*25	97·0	·676	65·57	9·5	9·1	…	11·2	143·5	24·00	337·00
26	96·8	…	…	…	…	…	…	…	21·00	358·00
*27	97·0	·677	65·66	9·6	9·2	…	11·3	143·3	24·00	382·00
*28	96·8	·671	64·95	8·4	8·1	…	10·0	144·3	24·00	406·00
*29	97·0	·671	65·08	8.7	8·4	…	10·3	144·6	24·00	430·00
30	97·1	·673	65·34	10·9	10·5	…	12·9	144·3	24·00	454·00
May.										
1	96·8	·670	64·85	10·8	10·4	…	12·8	144·5	24·00	478·00
2	96·7	·669	64·69	10·5	10·1	…	12·4	144·5	24·00	502·00
3	96·9	…	…	…	…	…	…	…	24·00	526·00
4	97·2	…	…	…	…	…	…	…	24·00	550·00
5	96·9	·674	65·31	11·1	10·7	…	13·2	143·8	24·00	574·00
6	97·0	·669	64·89	10·0	9·6	…	11·8	145·0	23·30	597·30
7	96·8	·670	64·85	10·8	10·4	…	12·8	144·5	24·00	621·30
8	96·9	…	…	…	…	…	…	…	24·00	645·30
9	97·0	·671	65·08	11·0	10·6	…	13·0	144·6	24·00	669·30
10	97·0	…	…	…	…	…	…	…	24·00	693·30
11	96·8	·671	64·95	10·3	9·9	…	12·2	144·3	24·00	717·30
12	95·9	…	…	…	…	…	…	…	24·00	741·30
13	97·4	…	…	…	…	…	…	…	23·30	765·00
14	97·2	·673	65·41	9·9	9·5	…	11·7	144·4	24·00	789·00
15	97·3	…	…	…	…	…	…	…	24·00	813·00
16	97·0	·671	65·08	10·3	9·9	…	12·2	144·6	24·00	837·00
17	97·2	…	…	…	…	…	…	…	24·00	861·00
18	97·0	·668	64·79	10·4	10·0	…	12·3	145·2	24·00	885·00
19	97·1	·669	64·96	8·7	8·4	…	10·3	145·1	24·00	909·00
20	97·2	…	…	…	…	…	…	…	24·00	933·00
21	97·0	·666	64·60	10·1	9·7	…	11·9	145·6	24·00	957·00
22	97·2	…	…	…	…	…	…	…	24·00	981·00
23	97·3	·664	64·60	9·5	9·1	…	11·2	146·5	24·00	1,005·00
24	97·0	…	…	…	…	…	…	…	24·00	1,029·00
*25	97·0	·668	64·79	7·4	7·1	…	8·7	145·2	24·00	1,053·00
26	…	…	…	…	…	…	…	…	11·30	1,064·30
28	…	…	…	…	…	…	…	…	…	…

Resistance Cold, 256. Discoloration, 2½.

Edison Lamp, No. 19, 99 Volts.

(Reduction Factor, 0·99. Resistance Cold, 250.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot	Hours.	Total Hours.
1885. April.	99·7	·714	71·19	16·15	16·02	4·44	19·50	139·6	0·45	0·45
11	....	....	....	10·4	10·3	....	12·6	....	3·45	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	97·8	·681	66·60	11·9	11·8	....	14·4	143·6	24·00	52·30
14	99·0	....	....	....	....	....	....	....	24·00	76·30
15	98·5	·683	67·28	12·4	12·3	....	15·0	144·2	24·00	100·30
16	99·1	....	....	....	....	....	....	....	24·00	124·30
17	99·0	·688	68·11	11·8	11·7	....	14·3	143·9	24·00	148·30
18	99·5	·692	68·86	12.9	12·8	....	15·6	143·8	24·00	172·30
19	99·8	....	....	....	....	....	....	....	24·00	196·30
20	97·8	·670	65·53	11·0	10·9	....	13·3	146·0	20·45	217·15
21	100·0	....	....	....	....	....	....	....	24·00	241·15
22	99·9	·681	67·35	11·5	11·4	....	13·9	145·2	24·00	265·15
23	99·1	....	....	....	....	....	....	....	24·00	289·15
24	99·0	·679	67·22	9·9	9·8	....	12·0	145·8	24·00	313·15
*25	99·4	·680	67·59	10·1	10·0	....	12·2	146·2	24·00	337·15
26	99·2	....	....	....	....	....	....	....	21·00	358·15
*27	99·0	·679	67·22	9·2	9·1	....	11·1	145·8	24·00	382·15
*28	99·0	·674	66·72	8·7	8·6	....	10·5	146·9	24·00	406·15
*29	99·2	·678	67·25	8·8	8·7	....	10·6	146·3	24·00	430·15
30	99·2	·676	67·06	10·9	10·8	....	13·2	146·7	24·00	454·15
May.										
1	99·0	·673	66·62	11·3	11·2	....	13·7	147·1	24·00	478·15
2	99·0	·674	66·72	11·2	11·1	....	13·5	146·9	24·00	502·15
3	99·0	....	....	....	....	....	....	....	24·00	526·15
4	99·4	....	....	....	....	....	....	....	24·00	550·15
5	99·3	·667	66·23	11·6	11·5	....	14·0	148·9	24·00	574·15
6	99·3	·671	66·63	10·2	10·1	....	12·3	148·0	23·30	597·45
7	99·1	·669	66·29	10·5	10·4	....	12·7	148·1	24·00	621·45
8	99·2	....	....	....	....	....	....	....	24·00	645·45
9	99·1	·670	66·40	11·0	10·9	....	13·3	147·9	24·00	669·45
10	99·2	....	....	....	....	....	....	....	24·00	693·45
11	99·0	·666	65·93	10·1	10·0	....	12·2	148·7	24·00	717·45
12	99·0	....	....	....	....	....	....	....	24·00	741·45
13	99·6	....	....	....	....	....	....	....	23·30	765·15
14	99·2	·667	66·16	9·8	9·7	....	11·8	148·7	24·00	789·15
15	99·3	....	....	....	....	....	....	....	24·00	813·15
16	99·0	·668	66·13	10·3	10·2	....	12·4	148·2	24·00	837·15
17	99·1	....	....	....	....	....	....	....	24·00	861·15
18	99·1	·666	66·00	10·3	10·2	....	12·4	148·8	24·00	885·15
19	99·1	·665	65·90	8·6	8·5	....	10·4	149·0	24·00	909·15
20	99·1	....	....	....	....	....	....	....	24·00	933·15
21	99·4	·664	66·00	10·1	10·0	....	12·2	149·7	24·00	957·15
22	99·3	....	....	....	....	....	....	....	24·00	981·15
23	99·1	·661	65·50	9·7	9·6	....	11·7	149·9	24·00	1,005·15
24	99·1	....	....	....	....	....	....	....	24·00	1,029·15
*25	99·0	·662	65·53	7·4	7·3	....	8·9	149·5	24·00	1,053·15
26	....	....	....	....	....	....	....	....	11·30	1,064·45
28	....	....	....	....	....	....	....	....	....	....

Resistance Cold, 267. **Discoloration, 2½.**

Edison Lamp, No. 20, 100 Volts.

(Reduction Factor, 0·97. Resistance Cold, 256.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	100·7	·696	70·09	16·23	15·82	4·43	19·56	144·7	0·30	0·30
11	...	...	...	15·5	15·0	...	18·6	...	3·45	4·15
12	...	...	...	...	...	...	...	...	24·00	28·15
13	98·6	·669	65·96	12·3	12·0	...	14·9	147·4	24·00	52·15
14	100·0	...	...	...	...	...	...	...	24·00	76·15
15	99·5	·669	66·57	13·0	12·6	...	15·6	148·7	24·00	100·15
16	100·4	...	...	...	...	...	...	...	24·00	124·15
17	99·7	·674	67·20	12·5	12·2	...	15·1	147·9	24·00	148·15
18	100·4	·677	67·97	13·9	13·5	...	16·7	148·3	24·00	172·15
19	100·4	...	...	...	...	...	...	...	24·00	196·15
20	98·5	·666	65·60	11·4	11·1	...	13·8	147·9	20·45	217·00
21	100·6	...	...	...	...	...	...	...	24·00	241·00
22	100·0	·673	67·30	12·2	11·8	...	14·6	148·6	24·00	265·00
23	100·5	...	...	...	...	...	...	...	24·00	289·00
24	100·2	·655	65·63	9·7	9·4	...	11·7	153·0	24·00	313·00
*25	100·6	·659	66·29	9·4	9·1	...	11·3	152·7	24·00	337·00
26	100·7	...	...	...	...	...	...	...	21·00	358·00
*27	100·3	·662	66·39	9·6	9·3	...	11·5	151·5	24·00	382·00
*28	100·2	·653	65·43	8·7	8·4	...	10·4	153·1	24·00	406·00
*29	100·1	·651	65·16	8·5	8·2	...	10·2	153·8	24·00	430·00
30	100·2	·654	65·53	10·6	10·3	...	12·8	153·2	24·00	454·00
May.										
1	100·1	·645	64·56	10·6	10·3	...	12·8	155·2	24·00	478·00
2	99·9	·650	64·93	10·3	10·0	...	12·4	153·7	24·00	502·00
3	99·9	...	...	...	...	...	...	...	24·00	526·00
4	99·8	...	...	...	...	...	...	...	24·00	550·00
5	99·9	·650	64·93	10·9	10·6	...	13·1	153·7	24·00	574·00
6	99·9	·648	64·73	10·1	9·8	...	12·2	154·2	23·30	597·30
7	99·6	·641	63·84	10·0	9·7	...	12·0	155·4	24·00	621·30
8	99·8	...	...	...	...	...	...	...	24·00	645·30
9	99·7	·646	64·41	10·5	10·2	...	12·6	154·3	24·00	669·30
10	100·0	...	...	...	...	...	...	...	24·00	693·30
11	99·6	·647	64·44	10·1	9·8	...	12·2	153·9	24·00	717·30
12	100·0	...	...	...	...	...	...	...	24·00	741·30
13	100·2	...	...	...	...	...	...	...	23·30	765·00
14	99·8	·643	64·17	9·5	9·2	...	11·4	155·2	24·00	789·00
15	99·9	...	...	...	...	...	...	...	24·00	813·00
16	99·7	·642	64·00	9·8	9·5	...	11·8	155·3	24·00	837·00
17	100·0	...	...	...	...	...	...	...	24·00	861·00
18	100·0	·639	63·90	9·9	9·6	...	11·9	156·5	24·00	885·00
19	99·5	·646	64·27	8·7	8·4	...	10·4	154·0	24·00	909·00
20	99·7	...	...	...	...	...	...	...	24·00	933·00
21	99·8	·642	64·07	9·9	9·6	...	11·9	155·5	24·00	957·00
22	99·9	...	...	...	...	...	...	...	24·00	981·00
23	99·9	·636	63·53	9·2	8·9	...	11·0	157·1	24·00	1,005·00
24	99·7	...	...	...	...	...	...	...	24·00	1,029·00
*25	100·0	·637	63·70	6·9	6·7	...	8·3	157·0	24·00	1,053·00
26	...	...	...	...	...	...	...	...	11·30	1,064·30
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 270. Discoloration, 2.

Stanley–Thompson Lamps, 44 Volts.

Stanley-Thompson Lamp, No. 1.

(Reduction Factor, 0·82. Resistance Cold, 80·7)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	44·40	1·096	48·66	15·2	12·39	3·92	15·36	40·51	2·00	2·00
11	....	....	....	15·8	13·0	....	16·1	....	3·45	5·45
12	....	....	....	....	....	....	....	....	24·00	29·45
13	43·05	1·041	44·81	12·5	10·2	....	12·7	41·35	24·00	53·45
14	42·80	1·023	43·78	12·2	10·0	....	12·4	41·84	24·00	77·45
15	43·55	....	....	....	....	....	....	....	24·00	101·45
16	43·75	1·025	44·85	13·1	10·8	....	13·4	42·68	24·00	125·45
17	43·30	....	....	....	....	....	....	....	24·00	149·45
18	43·35	1·004	43·52	11·7	9·6	....	11·9	43·18	24·00	173·45
19	44·35	....	....	....	....	....	....	....	24·00	197·45
20	43·20	·972	41·99	9·9	8·1	....	10·0	44·44	20·45	218·30
21	44·15	....	....	....	....	....	....	....	24·00	242·30
22	43·55	·965	42·02	9·0	7·4	....	9·2	45·13	24·00	266·30
23	43·95	·964	42·36	8·0	6·6	....	8·2	45·59	24·00	290·30
24	44·25	....	....	....	....	....	....	....	18·15	308·45

Carbon broke at side of loop 6.10 P.M., April 24, 1885. Discoloration, 4½.

Stanley-Thompson Lamp, No. 2.

(Reduction Factor, 0·79. Resistance Cold, 84.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	44·45	1·039	46·18	14·0	11·10	4·16	13·38	42·78	1·30	1·30
11	....	....	....	17·0	14·3	....	17·3	....	3·45	5·15
12	....	....	....	....	....	....	....	....	24·00	29·15
13	44·10	1·001	44·14	12·2	9·7	....	11·7	44·06	24·00	53·15
14	43·90	....	....	....	....	....	....	....	24·00	77·15
15	44·10	·980	43·22	13·1	10·4	....	12·6	45·00	24·00	101·15
16	45·50	....	....	....	....	....	....	....	24·00	125·15
17	....	....	....	....	....	....	....	....	17·45	143·00

Carbon broke at side of loop 5.45 P.M., April 17, 1885. Discoloration, 3½.

Stanley-Thompson Lamp, No. 3.

(Reduction Factor, 0·81. Resistance Cold, 79·5.)

Date	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·90	1·068	46·88	19·7	15·88	2·95	19·46	41·10	1·15	1·15
11	....	....	....	22·2	18·0	....	22·1	....	3·45	5·00
12	....	....	....	....	....	....	....	....	24·00	29·00
13	45·40	1·027	46·62	16·8	13·6	....	16·7	44·21	24·00	53·00
14	46·25	....	....	....	....	....	....	....	24·00	77·00
15	46·90	·980	45·96	13·9	11·3	....	13·9	47·86	24·00	101·00
16	48·85	....	....	....	....	....	....	....	24·00	125·00
17	....	....	....	....	....	....	....	....	11·30	136·30

Carbon broke at side of loop, 11.30 A.M., April 17, 1885. Discoloration, 4½.

Stanley-Thompson Lamp, No. 4.

(Reduction Factor, 0·77. Resistance Cold, 79·2.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·90	1·080	47·41	18·3	14·07	3·36	17·40	40·65	1·15	1·15
11	....	....	....	18·5	14·2	....	17·6	....	3·45	5·00
12	....	....	....	....	....	....	....	....	24·00	29·00
13	43·55	1·042	45·38	13·9	10·7	....	13·3	41·79	24·00	53·00
14	43·55	1·025	44·44	12·5	9·6	....	11·9	42·29	24·00	77·00
15	43·80	....	....	....	....	....	....	....	24·00	101·00
16	44·75	1·038	46·45	15·0	11·6	....	14·4	43·11	24·00	125·00
17	43·70	....	....	....	....	....	....	....	24·00	149·00
18	44·55	1·000	44·55	12·5	9·6	....	11·9	44·55	24·00	173·00
19	....	....	....	....	....	....	....	....	5·00	178·00

***Carbon broke at middle of loop 5·00 A. M., April 19, 1885. Discoloration, 4.**

Stanley-Thompson Lamp, No. 6.

(Reduction Factor, 0·79. Resistance Cold, 85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·90	1·001	43·94	13·1	10·31	4·26	12·58	43·86	1·00	1·00
11	....	....	....	16·2	12·8	....	15·6	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	43·20	·983	42·46	12·3	9·7	....	11·8	43·95	24·00	52·45
14	43·00	·978	42·05	11·3	8·9	....	10·9	43·97	24·00	76·45
15	43·50	....	....	....	....	....	....	....	24·00	100·45
16	44·10	·996	43·92	14·4	11·4	....	13·9	44·28	24·00	124·45
17	43·70	....	....	....	....	....	....	....	24·00	148·45
18	44·10	·972	42·86	12·4	9·8	....	12·0	45·37	24·00	172·45
19	44·90	....	....	....	....	....	....	....	24·00	196·45
20	43·55	·945	41·15	11·1	8·8	....	10·7	46·09	20·45	217·30
21	44·25	....	....	....	....	....	....	....	24·00	241·30
22	43·90	·939	41·22	10·1	8·0	....	9·8	46·75	24·00	265·30
23	44·20	·939	41·50	8·7	6·9	....	8·4	47·07	22·45	288·15

Carbon broke at side of loop 10.45 P.M., April 23, 1885. Discoloration, 3½.

Stanley-Thompson Lamp, No. 7.

(Reduction Factor, 0·80. Resistance Cold, 78.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·90	1·078	47·32	15·5	12·46	3·79	15·15	40·72	1·15	1·15
11	....	....	....	21·5	17·2	....	21·0	....	3·45	5·00
12	....	....	....	....	....	....	....	....	24·00	29·00
13	41·65	1·030	42·90	13·2	10·5	....	12·8	40·44	24·00	53·00
14	41·00	....	....	....	....	....	....	....	24·00	77·00
15	40·40	·981	39·63	11·0	8·8	....	10·7	41·18	24·00	101·00
16	41·00	....	....	....	....	....	....	....	24·00	125·00
17	43·00	....	....	....	....	....	....	....	23·00	148·00
18	43·30	1·043	45·16	15·4	12·3	....	15·0	41·52	24·00	172·00
19	43·40	....	....	....	....	....	....	....	24·00	196·00
20	42·40	·998	42·31	12·0	9·6	....	11·7	42·49	20·45	216·45
21	42·95	....	....	....	....	....	....	....	24·00	240·45
22	43·15	·993	42·84	11·6	9·3	....	11·3	43·45	24·00	264·45
23	43·35	·989	42·87	11·2	9·0	....	11·0	43·83	18·45	283·30
24	43·30	....	....	....	....	....	....	....	19·30	303·00

Carbon broke at middle of loop 7.35 P.M., April 24, 1885. Discoloration, 4.

Stanley-Thompson Lamp, No. 8.

(Reduction Factor, 0·87. Resistance Cold, 79·8.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·00	1·044	45·83	12·1	10·58	4·33	12·92	42·05	1·15	1·15
11	...	...	...	14·2	12·4	...	15·1	...	3·45	5·00
12	...	...	...	...	...	...	...	...	24·00	29·00
13	42·30	·998	42·21	10·4	9·1	...	11·1	42·39	24·00	53·00
14	42·10	...	...	...	...	...	...	...	24·00	77·00
15	41·70	·977	40·74	10·3	9·0	...	11·0	42·68	24·00	101·00
16	42·60	...	...	...	...	...	...	...	24·00	125·00
17	43·10	...	...	...	...	...	...	...	24·00	149·00
18	43·10	1·013	43·66	12·7	11·0	...	13·4	42·55	24·00	173·00
19	43·05	...	...	...	...	...	...	...	24·00	197·00
20	42·15	·982	41·39	10·6	9·2	...	11·2	42·92	20·45	217·45
21	41·85	...	...	...	...	...	...	...	24·00	241·45
22	42·50	·987	41·94	10·8	9·4	...	11·5	43·06	24·00	265·45
23	43·70	1·018	44·48	11·2	9·7	...	11·8	42·93	17·00	282·45
24	43·35	...	...	...	...	...	...	...	12·45	295·30
*25	43·95	1·001	43·99	10·5	9·1	...	11·1	43·91	24·00	319·30
26	13·70	...	...	...	...	...	...	...	21·00	340·30
*27	43·85	1·001	43·89	10·8	9·4	...	11·5	43·81	24·00	364·30
*28	44·25	1·002	44·33	9·3	8.1	...	9·9	44·16	24·00	388·30
*29	44·10	·992	43·74	9·2	8·0	...	9·8	44·46	24·00	412·30
30	44·25	·990	43·80	11·9	10·4	...	12·7	44·70	24·00	436·30
May.										
1	44·25	·980	43·36	10·5	9·1	...	11·1	45·15	24·00	460·30
2	44·15	·970	42·82	9·7	8·4	...	10·2	45·52	24·00	484·30
3	44·00	...	...	...	...	...	...	...	24·00	508·30
4	44·35	...	...	...	...	...	...	...	24·00	532·30
5	44·30	·964	42·70	10·0	8·7	...	10·6	45·95	24·00	556·30
6	43·65	·941	41·07	8·1	7·0	...	8·5	46·39	23·30	580·00
7	43·80	...	...	...	...	...	...	...	24·00	604·00
8	43·80	...	...	...	...	...	...	...	24·00	628·00
9	43·70	·936	40·90	8·7	7·6	...	9·3	46·69	24·00	652·00
10	44·05	...	...	...	...	...	...	...	24·00	676·00
11	44·05	·937	41·27	8·1	7·0	...	8·5	47·01	24·00	700·00
12	43·95	...	...	...	...	...	...	...	24·00	724·00
13	43·90	...	...	...	...	...	...	...	23·30	747·30
14	44·20	·935	41·32	8·4	7·3	...	8·9	47·27	24·00	771·30
15	44·25	...	...	...	...	...	...	...	24·00	795·30
16	44·20	·935	41·32	8·5	7·4	...	9·0	47·27	24·00	819·30
17	44·45	...	...	...	...	...	...	...	24·00	843·30
18	44·05	·927	40·83	8·5	7·4	...	9·0	47·52	24·00	867·30
19	44·15	...	...	...	...	...	...	...	24·00	891·30
20	44·05	·924	40·70	8·0	7·0	...	8·5	47·67	24·00	915·30
21	43·95	...	...	...	...	...	...	...	24·00	939·30
22	43·85	·896	39·29	7·2	6·3	...	7·7	48·94	24·00	963·30
23	43·95	·897	39·42	6·2	5·4	...	6·6	49·00	24·00	987·30
24	44·00	...	...	...	...	...	...	...	24·00	1,011·30
*25	44·15	·896	39·55	5·1	4·4	...	5·4	49·27	24·00	1,035·30
26	...	...	...	...	...	...	...	...	11·30	1,047·00
28	...	...	...	...	...	...	...	...	...	...

Resistance Cold, 92·0. Discoloration, 4.

Stanley-Thompson Lamp, No. 9.

(Reduction Factor, 0·80. Resistance Cold, 83.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·80	1·036	45.37	20·4	16·29	2·78	19·59	42·28	1·00	1·00
11	....	....	....	22·4	17·9	....	21·5	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	....	....	....	....	....	....	....	....	11·00	39·45

Carbon broke at side of loop near shank 11.00 A. M., April 13, 1885. Discoloration, 2½.

Stanley-Thompson Lamp, No. 10.

(Reduction Factor, 0·83. Resistance Cold, 82·4.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·75	1·031	45·10	19·3	15·94	2·83	19·29	42·43	1·00	1·00
11	....	....	....	19·5	16·2	....	19·6	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	42·40	·973	41·26	13·6	11·3	....	13·7	43·58	22·15	51·00
14	42·25	·951	40·18	13·4	11·1	....	13·4	44·43	24·00	75·00
15	43·20	....	....	....	....	....	....	....	24·00	99·00
16	43·15	·941	40·60	14·4	12·0	....	14·5	45·86	23·00	122·00
17	42·35	....	....	....	....	....	....	....	11·30	133·30
18	44·40	·956	42·44	15·7	13·0	....	15·7	46·44	24·00	157·30
19	44·10	....	....	....	....	....	....	....	24·00	181·30
20	43·55	·896	39·02	11·3	9·4	....	11·4	48·60	20·45	202·15
21	....	....	....	....	....	....	....	....	4·00	206·15

Carbon broke at middle of loop 4.00 A. M., April 21, 1885. Discoloration, 3½.

Stanley-Thompson Lamp, No. 11.

(Reduction Factor, 0·80. Resistance Cold, 79·0.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	43·90	1·059	46·49	19·1	15·19	3·06	19·28	41·45	1·00	1·00
11	…	…	…	24·2	19·4	…	24·6	…	3·45	4·45
12	…	…	…	…	…	…	…	…	24·00	28·45
13	44·10	1·051	46·34	16·5	13·2	…	16·8	41·96	24·00	52·45
14	44·75	1·036	46·36	15·5	12·4	…	15·7	43·20	24·00	76·45
15	45·10	…	…	…	…	…	…	…	24·00	100·45
16	44·25	·975	43·15	12·8	10·2	…	13·0	45·39	24·00	124·45
17	44·10	…	…	…	…	…	…	…	24·00	148·45
18	44·65	·954	42·59	10·4	8·3	…	10·5	46·80	24·00	172·45
19	43·95	…	…	…	…	…	…	…	24·00	196·45
20	42·75	·899	38·43	7·8	6·2	…	7·9	47·55	20·45	217·30
21	43·60	…	…	…	…	…	…	…	24·00	241·30
22	43·50	·901	39·19	7·4	5·9	…	7·5	48·28	24·00	265·30
23	…	…	…	…	…	…	…	…	9·30	275·00

Carbon broke at loop 9.30 A. M., April 23, 1885. Discoloration, 4½.

Stanley-Thompson Lamp, No. 12.

(Reduction Factor, ·80, not determined.)

Date	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April. 19	43·30	·887	38·41	9·6	…	…	…	48·82	9·00	9·00
20	43·25	·862	37·28	9·7	…	…	…	50·17	20·45	29·45
21	44·10	…	…	…	…	…	…	…	24·00	53·45
22	43·80	·860	37·66	9·5	…	…	…	50·93	24·00	77·45
23	43·80	·858	37·58	8·2	…	…	…	51·05	24·00	101·45
24	43·75	…	…	…	…	…	…	…	24·00	125·45
*25	44·35	·857	38·00	8·2	…	…	…	51·75	24·00	149·45
26	43·90	…	…	…	…	…	…	…	21·00	170·45
*27	43·90	·857	37·62	8·6	…	…	…	51·23	24·00	194·45
*28	44·25	·858	37·95	8·0	…	…	…	51·57	24·00	218·45
*29	44·35	·853	37·83	8·3	…	…	…	51·99	24·00	242·45
30	43·95	·844	37·09	10·6	…	…	…	52·07	24·00	266·45
May.										
1	44·15	·841	37·13	9·7	…	…	…	52·50	24·00	290·45
2	44·25	·841	37·21	9·7	…	…	…	52·62	16·30	307·15

Carbon destroyed by too high potential 4.30 P. M., May 2, 1885. Discoloration, 6.

Stanley–Thompson Lamps, 96 Volts.

Stanley-Thompson Lamp, No. 26.

(Reduction Factor, 0·82. Resistance Cold, 330.)

Date.	Volts.	Amperes.	Volts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·4	·578	55·72	15·85	13·10	4·25	15·73	166·8	1·00	1·00
11				18·5	15·2		18·2		3·45	4·45
12									24·00	28·45
13	95·1	·554	52·60	14·2	11·6		13·9	171·7	24·00	52·45
14	96·2								24·00	76·45
15									1·30	78·15

Carbon broke at side of loop 1.30 A. M., April 15, 1885. Discoloration, 2.

Stanley-Thompson Lamp, No. 28.

(Reduction Factor, 0·86. Resistance Cold, 328.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·5	·584	56·35	19·80	17·11	3·29	19·78	165·2	1·45	1·45
11				23·8	20·5		23·8		3·45	5·30
12									24·00	29·30
13	95·7	·562	53·78	17·2	14·8		17·2	170·3	24·00	53·30
14	96·9								24·00	77·30
15	96·9	·541	52·43	15·5	13·3		15·4	179·1	24·00	101·30
16	98·8								24·00	125·30
17	98·3								24·00	149·30
18	96·8	·519	50·24	12·2	10·5		12·2	186·5	24·00	173·30
19	98·8								24·00	197·30
20	95·4	·497	47·41	10·2	8·8		10·2	192·0	20·45	218·15
21									14·45	233·00

Carbon broke at side of loop 2. 45 P. M., April 21, 1885. Discoloration, 3.

Stanley-Thompson Lamp, No. 29.

(Reduction Factor, 0·83. Resistance Cold, 368.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·4	·537	51·76	19·82	16·49	3·14	19·48	179·5	0·45	0·45
11	....	....	....	21·8	18·1	....	21·4	....	3·45	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	95·0	·491	46·64	14·9	12·4	....	14·6	193·5	24·00	52·30
14	96·2	....	....	....	....	....	....	....	24·00	76·30
15	96·3	·482	46·41	14·9	12·4	....	14·6	199·8	24·00	100·30
16	98·4	....	....	....	....	....	....	....	24·00	124·30
17	96·6	....	....	....	....	....	....	....	24·00	148·30
18	95·9	·459	44·01	12·1	10·0	....	11·8	208·9	24·00	172·30
19	....	....	....	....	....	....	....	....	3·30	176·00

Carbon broke at side of loop 3.30 A. M., April 19, 1885. Discoloration, 3½.

Stanley-Thompson Lamp, No. 33.

(Reduction Factor, 0·82. Resistance Cold, 365.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·4	·528	50·90	17·45	14·32	3·55	17·17	182·6	0·30	0·30
11	....	....	....	19·2	15·7	....	18·8	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	95·0	·487	46·27	11·6	9·5	....	11·4	195·1	24·00	52·15
14	96·0	....	....	....	....	....	....	....	24·00	76·15
15	96·0	·484	46·46	12·3	10·1	....	12·1	198·3	24·00	100·15
16	98·1	....	....	....	....	....	....	....	24·00	124·15
17	96·5	....	....	....	....	....	....	....	24·00	148·15
18	95·8	·472	45·22	11·4	9·3	....	11·2	203·0	24·00	172·15
19	96·7	....	....	....	....	....	....	....	24·00	196·15
20	95·0	·463	43·98	10·0	8·2	....	9·8	205·2	20·45	217·00
21	96·5	·471	45·45	10·5	8·6	....	10·3	204·9	24·00	241·00
22	96·6	....	....	....	....	....	....	....	15·30	256·30

Carbon broke at side of loop—3.30 P. M., April 22, 1885. Discoloration, 2.

Stanley-Thompson Lamp, No. 30.

(Reduction Factor, 0·84. Resistance Cold, 339.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·3	·544	53·35	15·85	12·94	4·12	15·65	173·8	0·45	0·45
11	…	…	…	15·8	13·3	…	16·1	…	3·45	4·30
12	…	…	…	…	…	…	…	…	24·00	28·30
13	94·9	·499	47·36	9·8	8·2	…	9·9	190·2	24·00	52·30
14	95·8	…	…	…	…	…	…	…	24·00	76·30
15	95·4	·504	48·08	11·3	9·5	…	11·5	189·3	24·00	100·30
16	97·2	…	…	…	…	…	…	…	24·00	124·30
17	95·7	…	…	…	…	…	…	…	24·00	148·30
18	95·6	·506	48·37	11·9	10·0	…	12·1	188·9	24·00	172·30
19	96·3	…	…	…	…	…	…	…	24·00	196·30
20	94·6	·499	47·20	10·4	8·7	…	10·5	189·6	20·45	217·15
21	96·1	·505	48·53	10·8	9·1	…	11·0	190·3	24·00	241·15
22	96·1	…	…	…	…	…	…	…	24·00	265·15
23	96·6	…	…	…	…	…	…	…	24·00	289·15
24	96·2	·498	47·90	9·5	8·0	…	9·7	193·2	24·00	313·15
*25	96·5	·498	48·05	9·2	7·7	…	9·3	193·8	24·00	337·15
26	96·2	…	…	…	…	…	…	…	21·00	358·15
*27	96·1	·492	47·28	8·8	7·4	…	9·0	195·3	24·00	382·15
*28	96·1	·492	47·28	7·6	6·4	…	7·7	195·3	24·00	406·15
*29	96·5	·492	47·47	7·9	6·6	…	8·0	196·1	24·00	430·15
30	96·1	·489	46·99	10·5	8·8	…	10·6	196·5	24·00	454·15
May.										
1	96·4	·489	47·14	10·2	8·6	…	10·4	197·1	24·00	478·15
2	96·4	·488	47·04	9·6	8·1	…	9·8	197·5	24·00	502·15
3	96·1	…	…	…	…	…	…	…	24·00	526·15
4	96·2	…	…	…	…	…	…	…	24·00	550·15
5	95·9	·483	46·32	9·3	7·8	…	9·4	198·6	24·00	574·15
6	96·0	·480	46·08	8·3	7·0	…	8·5	200·0	23·30	597·45
7	96·0	…	…	…	…	…	…	…	24·00	621·45
8	96·0	…	…	…	…	…	…	…	24·00	645·45
9	95·8	·477	45·69	9·2	7·7	…	9·3	200·8	24·00	669·45
10	96·0	…	…	…	…	…	…	…	24·00	693·45
11	96·0	·477	45·79	8·4	7·1	…	8·6	201·3	24·00	717·45
12	95·9	…	…	…	…	…	…	…	24·00	741·45
13	95·5	…	…	…	…	…	…	…	23·30	765·15
14	96·1	·475	45·64	8·1	6·8	…	8·2	202·3	24·00	789·15
15	96·3	…	…	…	…	…	…	…	24·00	813·15
16	96·0	·476	45·69	8·5	7·1	…	8·6	201·7	24·00	837·15
17	96·1	…	…	…	…	…	…	…	24·00	861·15
18	96·1	·472	45·35	8·5	7·1	…	8·6	203·6	24·00	885·15
19	96·0	·473	45·40	7·1	6·0	…	7·3	203·0	24·00	909·15
20	96·1	…	…	…	…	…	…	…	24·00	933·15
21	96·2	·469	45·11	8·3	7·0	…	8·5	205·1	24·00	957·15
22	95·7	…	…	…	…	…	…	…	24·00	981·15
23	96·2	·470	45·21	7·5	6·3	…	7·6	204·7	24·00	1,005·15
24	96·1	…	…	…	…	…	…	…	24·00	1,029·15
*25	96·1	·470	45·17	6·1	5·1	…	6·2	204·5	24·00	1,053·15
26	…	…	…	…	…	…	…	…	11·30	1,064·45
28	…	…	…	…	…	…	…	…	…	…

Resistance Cold, 339. Discoloration, 3.

Stanley-Thompson Lamp, No. 34.

(Reduction Factor, 0·89. Resistance Cold, 349.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·4	·558	53·79	17·05	14·17	3·79	16·95	172·8	0·45	0·45
11				19·4	17·3	....	20·6		3·45	4·30
12				....	....	....	....		24·00	28·30
13	94·8	·534	50·62	13·3	11·9	....	14·0	177·5	24·00	52·30
14	96·0	....	....	....	....	....	....	....	24·00	76·30
15	95·5	·529	50·52	14·6	13·0	....	15·5	180·5	24·00	100·30
16	97·6	....	....	....	....	....	....	....	24·00	124·30
17	96·2	....	....	....	....	....	....	....	24·00	148·30
18	96·4	·527	50·80	14·3	12·7	....	15·1	182·9	24·00	172·30
19	97·3	....	....	....	....	....	....	....	24·00	196·30
20	94·5	·508	48·00	11·6	10·3	....	12·3	186·0	20·45	217·15
21	96·2	·518	49·83	12·4	11·0	....	13·1	185·7	24·00	241·15
22	96·2	....	....	....	....	....	....	....	24·00	265·15
23	96·4	....	....	....	....	....	....	....	24·00	289·15
24	96·5	·509	49·11	10·9	9·7	....	11·5	189·6	24·00	313·15
*25	96·6	·510	49·26	10·7	9·5	....	11·3	189·4	24·00	337·15
26	96·0	....	....	....	....	....	....	....	21·00	358·15
*27	96·1	·502	48·24	9·8	8·7	....	10·4	191·4	24·00	382·15
*28	96·2	·493	47·42	8·0	7·1	....	8·4	195·1	24·00	406·15
*29	96·3	·499	48·05	8·6	7·7	....	9·2	193·0	24·00	430·15
30	96·6	·501	48·39	11·6	10·3	....	12·3	192·8	24·00	454·15
May.										
1	96·3	·493	47·47	11·3	10·1	....	12·0	195·3	24·00	478·15
2	96·5	·495	47·76	10·0	8·9	....	10·6	195·0	24·00	502·15
3	95·8	....	....	....	....	....	....	....	22·30	524·45

Carbon broke at side of loop 10.30 P. M., May 3, 1885. Discoloration, 3½.

Stanley-Thompson Lamp, No. 35.

(Reduction Factor, 0·82. Resistance Cold, 350.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·4	·552	53·21	16·38	13·72	3·87	16·59	174·6	0·45	0·45
11				17·8	14·6	....	17·8	....	3·45	4·30
12				....	....	....	....	....	24·00	28·30
13	95·2	·535	50·93	12·5	10·2	....	12·4	177·9	24·00	52·30
14	96·2	....	....	....	....	....	....	....	24·00	76·30
15	95·9	·524	50·25	12·7	10·4	....	12·7	183·0	23·00	99·30

Carbon broke at middle of loop 11.00 P. M., April 15, 1885. Discoloration, 2.

Stanley-Thompson Lamp, No. 36.

(Reduction Factor, 0·83. Resistance Cold, 336.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	96·2	·576	55·41	19·92	16·49	3·36	19·55	167·0	0·45	0·45
11	....	....	....	23·8	19·8	....	23·6	....	3·45	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	95·4	·545	52·00	14·4	12·0	....	14·3	175·0	24·00	52·30
14	96·2	....	....	....	....	....	....	....	24·00	76·30
15	95·8	·531	50·87	13·7	11·4	....	13·6	180·4	24·00	100·30
16	98·4	....	....	....	....	....	....	....	24·00	124·30
17	97·2	....	....	....	....	....	....	....	24·00	148·30
18	95·2	·505	48·07	10·9	9·0	....	10·7	188·5	24·00	172·30
19	95·8	....	....	....	....	....	....	....	24·00	196·30
20	94·0	·495	46·53	9·4	7·8	....	9·3	189·9	20·45	217·15
21	95·7	·497	47·56	9·9	8·2	....	9·8	192·6	24·00	241·15
22	95·9	....	....	....	....	....	....	....	24·00	265·15
23	96·1	....	....	....	....	....	....	....	24·00	289·15
24	....	....	....	....	....	....	....	....	11·30	300·45

Carbon broke at side of loop 11.30 A. M., April 24, 1885. Disooloration, 3½.

Stanley-Thompson Lamp, No. 37.

Reduction Factor, 0·81. Resistance Cold, 350.

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	97·2	·584	51·90	17·55	14·28	3·63	17·29	182·0	0·45	0·45
11	......	......	......	15·5	12·6	......	15·2	......	3·45	4·30
12	......	......	......	......	......	......	......	......	24·00	28·30
13	95·5	·494	47·18	12·5	10·1	......	12·2	193·3	24·00	52·30
14	95·7	......	......	......	......	......	......	......	24·00	76·30
15	95·0	·484	45·98	12·2	9·9	......	12·0	196·3	24·00	100·30
16	97·6	......	......	......	......	......	......	......	24·00	124·30
17	96·3	......	......	......	......	......	......	......	24·00	148·30
18	96·5	·481	46·41	12·0	9·7	......	11·7	200·6	24·00	172·30
19	97·1	......	......	......	......	......	......	......	24·00	196·30
20	95·9	·474	45·45	10·9	8·8	......	10·6	202·3	20·45	217·15
21	97·0	·480	46·56	10·2	8·3	......	10·0	202·1	24·00	241·15
22	96·9	......	......	......	......	......	......	......	24·00	265·15
23	96·3	......	......	......	......	......	......	......	24·00	289·15
24	96·2	·470	45·22	8·8	7·1	......	8·6	204·7	24·00	313·15
*25	96·4	·466	44·92	8·1	6·6	......	8·0	206·9	24·00	337·15
26	96·0	......	......	......	......	......	......	......	21·00	358·15
*27	95·9	·463	44·40	8·0	6·5	......	7·9	207·1	24·00	382·15
*28	96·0	·461	44·25	7·2	5·8	......	7·0	208·2	24·00	406·15
*29	96·2	·462	44·44	7·1	5·8	......	7·0	208·2	24·00	430·15
30	96·3	·461	44·39	9·5	7·7	......	9·3	208·9	24·00	454·15
May.										
1	96·1	·460	44·20	9·4	7·6	......	9·2	208·9	24·00	478·15
2	96·3	·460	44·29	8·5	6·9	......	8·3	209·3	24·00	502·15
3	96·0	......	......	......	......	......	......	......	24·00	526·15
4	96·3	......	......	......	......	......	......	......	24·00	550·15
5	96·0	·456	43·77	8·9	7·2	......	8·7	210·5	24·00	574·15
6	96·0	·455	43·68	8·1	6·5	......	7·9	211·0	23·30	597·45
7	96·1	......	......	......	......	......	......	......	24·00	621·45
8	96·2	......	......	......	......	......	......	......	24·00	645·45
9	96·0	·450	43·20	8·6	7·0	......	8·5	213·3	24·00	669·45
10	96·3	......	......	......	......	......	......	......	24·00	693·45
11	96·3	·452	43·52	8·2	6·6	......	8·0	213·1	24·00	717·45
12	96·2	......	......	......	......	......	......	......	24·00	741·45
13	97·7	......	......	......	......	......	......	......	23·30	765·15
14	95·6	·447	42·73	7·9	6·4	......	7·7	213·9	24·00	789·15
15	95·9	......	......	......	......	......	......	......	24·00	813·15
16	95·5	·444	42·40	7·7	6·2	......	7·5	215·1	24·00	837·15
17	96·0	......	......	......	......	......	......	......	24·00	861·15
18	95·9	·445	42·67	8·3	6·7	......	8·1	215·5	20·15	881·30

Carbon broke at side of loop 8.15 P. M., May 18, 1885. Discoloration 2½.

Stanley-Thompson Lamp, No. 41.

(Reduction Factor, 0·81. Resistance Cold, 340.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	97·2	·567	55·11	15·97	12·98	4·26	15·51	171·4	0·45	0·45
11	....	....	....	15·0	12·2	....	14·6	....	3·45	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	95·6	·526	50·29	13·6	11·0	....	13·2	181·8	24·00	52·30
14	96·3	·529	50·94	13·4	10·9	....	13·1	182·0	24·00	76·30
15	96·3	....	....	....	....	....	....	....	24·00	100·30
16	98·1	·531	52·09	16·7	13·5	....	16·2	184·7	24·00	124·30
17	97·5	·529	51·57	14·0	11·4	....	13·7	184·3	24·00	148·30
18	97·7	....	....	....	....	....	....	....	24·00	172·30
19	97·7	·519	50·70	12·1	9·8	....	11·8	188·2	24·00	196·30
20	96·8	....	....	....	....	....	....	....	20·45	217·15
21	97·0	·513	49·75	11·8	9·2	....	11·0	189·1	24·00	241·15
22	95·9	....	....	....	....	....	....	....	24·00	265·15
23	96·1	·501	48·15	9·8	7·5	....	9·0	191·8	24·00	289·15
24	95·9	....	....	....	....	....	....	....	24·00	313·15
*25	95·9	·499	47·85	8·1	6·6	....	7·9	192·2	24·00	337·15
26	96·2	....	....	....	....	....	....	....	21·00	358·15
*27	95·8	·492	47·13	9·1	7·4	....	8·9	194·7	24·00	382·15
*28	96·1	·496	47·66	7·5	6·1	....	7·3	193·7	24·00	406·15
*29	96·0	·495	47·52	7·9	6·4	....	7·7	193·9	24·00	430·15
30	95·9	·496	47·56	10·6	8·6	....	10·3	193·3	24·00	454·15
May.										
1	96·1	·492	47·28	9·9	8·0	....	9·6	195·3	24·00	478·15
2	96·0	·492	47·23	9·5	7·7	....	9·2	195·1	24·00	502·15
3	96·1	....	....	....	....	....	....	....	24·00	526·15
4	96·3	....	....	....	....	....	....	....	24·00	550·15
5	96·2	·491	47·23	9·9	8·0	....	9·6	195·9	24·00	574·15
6	96·0	·488	46·84	9·4	7·6	....	9·1	196·7	23·30	597·45
7	96·3	....	....	....	....	....	....	....	24·00	621·45
8	96·3	....	....	....	....	....	....	....	24·00	615·45
9	96·1	·485	46·60	9·7	7·9	....	9·5	198·1	24·00	669·45
10	....	....	....	....	....	....	....	....	12·45	682·30

Carbon broke at side of loop 12.45 P.M., May 10, 1885. Discoloration, 2½.

Woodhouse and Rawson Lamps, 55 Volts.

Woodhouse and Rawson Lamp, No. 1.

(Reduction Factor, 1·07. Resistance Cold, 98.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·30	1·162	64·26	17·7	19·01	3·38	22·14	47·59	1·15	1·15
11	....	....	....	19·4	20·8	....	24·1	....	3·15	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	....	....	....	....	....	....	....	....	12·30	41·00

Carbon broke at middle of loop at 12.30 P.M., April 13, 1885. Discoloration, 3.

Woodhouse and Rawson Lamp, No. 3.

(Reduction Factor, 1·14. Resistance Cold, 102.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·2	1·162	64·14	17·6	20·06	3·19	24·39	47·50	0·45	0·45
11	....	....	....	26·4	30·1	....	36·7	....	3·15	4·00
12	....	....	....	....	....	....	....	....	24·00	28·09
13	55·35	1·184	65·53	19·6	22·3	....	27·2	46·75	23·45	51·45
14	56·70	1·179	66·85	18·5	21·1	....	25·7	48·09	24·00	75·45
15	56·40	....	....	....	....	....	....	....	24·00	99·45
16	55·90	1·120	62·60	16·3	18·6	....	22·7	49·91	24·00	123·45
17	56·50	....	....	....	....	....	....	....	21·00	147·45
18	53·50	1·016	55·96	11·0	12·5	....	15·3	51·15	24·00	171·45
19	56·30	....	....	....	....	....	....	....	24·00	195·45
20	54·20	1·025	55·55	10·5	12·0	....	14·6	52·88	17·45	213·30

Carbon broke at middle of loop 9.00 P.M., April 20, 1885. Discoloration, 4½.

Woodhouse and Rawson Lamp, No. 4.

(Reduction Factor, 1·05. Resistance Cold, 108.)

Date.	Volts.	Ampères.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·15	1·067	58·29	17·2	17·99	3·24	21·27	52·18	1·00	1·00
11	...	...	...	22·3	23·4	...	27·7	...	3·30	4·30
12	...	...	...	...	...	...	...	...	24·00	28·30
13	53·40	1·023	54·62	12·7	13·3	...	15·7	52·20	24·00	52·30
14	53·70	1·015	54·50	12·5	13·2	...	15·6	52·91	24·00	76·30
15	54·15	...	...	...	...	...	...	...	24·00	100·30
16	...	...	...	...	...	...	...	...	21·45	122·15
17	56·05	...	...	...	...	...	...	...	24·00	146·15
18	55·60	·987	54·87	12·3	12·9	...	15·3	56·33	24·00	170·15
19	56·50	...	...	...	...	...	...	...	24·00	194·15
20	...	...	...	...	...	...	...	...	8·45	203·00

Carbon broke at side of loop 8.40 A.M., April 20, 1885. Discoloration, 4½.

Woodhouse and Rawson Lamp, No. 5.

(Reduction Factor, 1·14. Resistance Cold, 118.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·40	1·000	55·40	12·3	13·97	3·96	16·31	55·40	0·45	0·45
11	...	...	...	17·0	19·4	...	22·7	...	3·45	4·30
12	...	...	...	...	...	...	...	...	24·00	28·30
13	53·35	·998	53·24	11·3	12·9	...	15·1	53·46	24·00	52·30
14	53·80	1·003	53·96	11·5	13·1	...	15·3	53·64	24·00	76·30
15	54·15	...	...	...	...	...	...	...	24·00	100·30
16	54·25	1·002	54·35	13·2	15·0	...	17·5	54·14	24·00	124·30
17	54·25	...	...	...	...	...	...	...	24·00	148·30
18	54·15	·993	53·77	11·0	12·5	...	14·6	54·53	24·00	172·30
19	54·95	...	...	...	...	...	...	...	24·00	196·30
20	53·05	·967	51·30	10·3	11·7	...	13·7	54·86	20·45	217·15
21	55·05	...	...	...	...	...	...	...	24·00	241·15
22	54·80	·987	54·08	11·5	13·1	...	15·3	55·52	24·00	265·15
23	54·95	·986	54·18	9·0	10·3	...	12·0	55·73	24·00	289·15
24	54·95	...	...	...	...	...	...	...	24·00	313·15
*25	55·10	·975	53·72	9·4	10·7	...	12·5	56·51	24·00	337·15
26	55·20	...	...	...	...	...	...	...	21·00	358·15
*27	54·70	·964	52·73	8·4	9·6	...	11·2	56·74	24·00	382·15
*28	55·10	·962	53·00	7·5	8·6	...	10·1	57·29	24·00	406·15
*29	55·20	·959	52·93	7·7	8·8	...	16·3	57·56	24·00	430·15
30	...	...	...	...	...	...	...	...	9·30	439·45

Carbon broke at middle of loop 9.30 A.M., April 30, 1885. Discoloration, 4½.

Woodhouse and Rawson Lamp, No. 6.

(Reduction Factor, 1·12. Resistance Cold, 124.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·30	·936	51·76	11·7	13·11	3·94	14·76	59·08	0·45	0·45
11	....	....	....	11·4	12·8	....	14·5	....	3·45	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	53·75	·899	48·32	9·3	10·4	....	11·8	59·79	24·00	52·30
14	53·00	·887	47·01	9·1	10·2	....	11·5	59·75	24·00	76·30
15	53·65	....	....	....	....	....	....	....	24·00	100·30
16	53·85	·898	48·35	10·7	11·9	....	13·4	59·97	24·00	124·30
17	54·80	....	....	....	....	....	....	....	24·00	148·30
18	54·35	·893	48·53	10·5	11·8	....	13·3	60·86	24·00	172·30
19	54·55	....	....	....	....	....	....	....	24·00	196·30
20	52·30	·857	44·82	8·7	9·7	....	11·0	61·03	20·45	217·15
21	53·10	....	....	....	....	....	....	....	24·00	241·15
22	52·85	·862	45·55	8·5	9·5	....	10·7	61·31	24·00	265·15
23	55·05	·886	48·77	9·7	10·9	....	12·3	62·13	24·00	289·15
24	54·95	....	....	....	....	....	....	....	24·00	313·15
*25	55·50	·885	49·11	8·8	9·9	....	11·1	62·71	24·00	337·15
26	55·10	....	....	....	....	....	....	....	21·00	358·15
*27	55·05	·870	47·89	8·6	9·6	....	10·8	63·28	24·00	382·15
28	....	....	....	....	....	....	....	....	13·00	395·15

Carbon broke at shank 1.00 P. M, April 28, 1885. Discoloration, 4.

Woodhouse and Rawson Lamp, No. 7.

(Reduction Factor, 1·00 Resistance Cold, 132.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885, April.	55·90	·914	51·09	15·5	15·53	3·29	19·45	61·16	0·45	0·45
11	....	....	....	16·6	16·6	....	20·8	....	8·45	4·30
12	....	....	....	....	....	....	....	....	24·00	28·30
13	55·25	·901	49·78	13·0	13·0	....	16·3	61·32	24·00	52·30
14	56·20	·887	49·85	12·7	12·7	....	15·9	63·36	24·00	76·30
15	56·30	....	....	....	....	....	....	....	24·00	100·30
16	55·90	·910	50·86	16·4	16·4	....	20·5	61·43	24·00	124·30
17	56·00	....	....	....	....	....	....	....	24·00	148·30
18	56·40	·895	50·47	15·0	15·0	....	18·8	63·02	24·00	172·30
19	57·10	....	....	....	....	....	....	....	24·00	196·30
20	55·20	·839	46·31	11·8	11·8	....	14·8	65·79	20·45	217·15
21	56·65	....	....	....	....	....	....	....	24·00	241·15
22	56·80	·864	49·07	12·4	12·4	....	15·5	65·74	24·00	265·15
23	55·10	·824	45·40	10·1	10·1	....	12·6	66·87	24·00	289·15
24	54·95	....	....	....	....	....	....	....	24·00	313·15
*25	55·55	·818	45·43	8·5	8·5	....	10·6	67·91	24·00	337·15
26	55·20	....	....	....	....	....	....	....	21·00	358·15
*27	54·95	·806	44·29	8·4	8·4	....	10·5	68·18	24·00	382·15
*28	55·30	·796	44·01	7·0	7·0	....	8·8	69·47	24·00	406·15
*29	55·45	·793	43·97	7·2	7·2	....	9·0	69·93	16·30	422·45

Carbon broke at side of loop 4.25 P. M., April 29, 1885. Discoloration 4½.

Woodhouse and Rawson Lamp, No. 8, 55 Volts.

(Reduction Factor, 1·07. Resistance Cold, 116.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	56·05	1·025	57·45	14·0	15·05	3·81	18·28	54·68	2·00	2·00
11	....	....	....	18·6	19·9	....	24·1	....	3·30	5·30
12	....	....	....	....	....	....	....	....	24·00	29·30
13	55·20	1·022	56·41	12·5	13·4	....	16·2	54·01	24·00	53·30
14	55·75	1·019	56·80	12·9	13·8	....	16·7	54·71	24·00	77·30
15	56·30	....	....	....	....	....	....	....	24·00	101·30
16	....	....	....	....	....	....	....	....	16·15	117·45

Carbon broke at side of loop 4.15 P. M., April 16, 1885. Discoloration, 3.

Woodhouse and Rawson Lamp, No. 9.

(Reduction Factor, 1·00. Resistance Cold, 106.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·95	1·125	62·94	18·50	18·43	3·41	22·01	49·73	1·00	1·00
11	......	......	......	17·2	17·2	......	20·5	......	3·45	4·45
12	......	......	......	......	......	......	......	......	24·00	28·45
13	52·95	1·082	57·29	12·8	12·8	......	15·2	48·94	24·00	52·45
14	53·55	1·093	58·53	13·2	13·2	......	15·7	48·99	24·00	76·45
15	55·60	......	......	......	......	......	......	......	24·00	100·45
16	56·30	1·120	63·06	17·3	17·3	......	20·6	50·27	24·00	124·45
17	56·70	......	......	......	......	......	......	......	24·00	148·45
18	54·00	1·052	56·80	10·8	10·8	......	12·8	51·33	24·00	172·45
19	54·70	......	......	......	......	......	......	......	24·00	196·45
20	53·10	1·024	54·37	9·6	9·6	......	11·4	51·86	20·45	217·30
21	54·55	......	......	......	......	......	......	......	24·00	241·30
22	55·00	1·047	57·58	10·5	10·5	......	12·5	52·53	24·00	265·30
23	55·25	1·043	57·62	9·1	9·1	......	10·8	52·97	24·00	289·30
24	55·30	......	......	......	......	......	......	......	24·00	313·30
*25	55·30	1·030	56·96	8·4	8·4	......	10·0	53·69	24·00	337·30
26	55·10	......	......	......	......	......	......	......	21·00	358·30
*27	54·85	1·015	55·67	7·8	7·8	......	9·3	54·04	24·00	382·30
*28	55·25	1·018	56·24	6·5	6·5	......	7·7	54·27	24·00	406·30
*29	55·45	1·020	56·55	6·7	6·7	......	8·0	54·36	24·00	430·30
30	55·25	1·012	55·91	8·7	8·7	......	10·4	54·60	24·00	454·30
May.										
1	55·35	1·011	55·95	8·0	8·0	......	9·5	54·75	24·00	478·30
2	55·10	1·002	55·21	7·0	7·0	......	8·3	54·99	24·00	502·30
3	54·85	......	......	......	......	......	......	......	24·00	526·30
4	55·10	......	......	......	......	......	......	......	24·00	550·30
5	55·10	·995	54·82	7·4	7·4	......	8·8	55·38	24·00	574·30
6	55·00	·986	54·23	6·7	6·7	......	8·0	55·78	23·30	598·00
7	55·10	......	......	......	......	......	......	......	24·00	622·00
8	55·25	......	......	......	......	......	......	......	24·00	646·00
9	55·10	·982	54·10	7·3	7·3	......	8·7	56·11	24·00	670·00
10	55·40	......	......	......	......	......	......	......	24·00	694·00
11	55·50	·984	54·61	7·0	7·0	......	8·3	56·40	21·30	715·30

Carbon broke at side of loop 9.30 P.M., May 11, 1885. Discoloration, 5.

Woodhouse and Rawson Lamp, No. 10.

(Reduction Factor, 1·18. Resistance Cold, 139.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	56·00	·805	45·08	10·40	12·19	3·69	14·38	69·57	1·30	1·30
22	....	....	....	....	....	....	....	....	6·15	7·45
23	55·10	·781	43·03	10·6	12·5	....	14·7	70·55	24·00	31·45
24	55·30	....	....	....	....	....	....	....	24·00	55·45
25	....	....	....	....	....	....	....	....	13·00	68·45

Carbon broke at side of loop 1.00 P. M., April 25, 1885. Discoloration, 2½.

Woodhouse and Rawson Lamp, No. 18 B.

(Reduction Factor, 1·19. Resistance Cold, 115.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	55·25	1·004	55·47	12·0	14·33	3·87	17·41	55·03	1·15	1·15
11	....	....	....	13·6	16·2	....	19·6	....	3·45	5·00
12	....	....	....	....	....	....	....	....	24·00	29·00
13	55·00	1·003	55·17	12·3	14·7	....	17·8	54·84	24·00	53·00
14	55·00	1·000	55·00	11·9	14·1	....	17·1	55·00	24·00	77·00
15	55·10	....	....	....	....	....	....	....	24·00	101·00
16	55·65	1·004	55·87	14·7	17·5	....	21·2	55·43	24·00	125·00
17	55·35	....	....	....	....	....	....	....	24·00	149·05
18	55·35	·991	54·85	13·3	15·8	....	19·1	55·85	24·00	173·00
19	56·45	....	....	....	....	....	....	....	24·00	197·00
20	54·85	·972	53·31	12·8	15·2	....	18·4	56·48	20·45	217·45
21	54·35	....	....	....	....	....	....	....	24·00	241·45
22	54·50	·956	52·10	10·8	12·9	....	15·6	57·01	24·00	265·45
23	....	....	....	....	....	....	....	....	11·45	277·30

Carbon broke at side of loop 11.45 A. M., April 23, 1885. Discoloration, 3½.

Woodhouse and Rawson, Second Lot.

*Woodhouse and Rawson Lamp, No. 30.**

(Reduction Factor, 1·08. Resistance Cold, 100.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	55·00	1·167	64·18	17·18	18·52	3·46	22·78	47·13	1·00	1·00
12	54·60	1·154	63·00	20·2	21·8	....	26·8	47·31	8·15	9·15
13	54·85	1·168	64·06	20·4	22·0	....	27·1	46·96	23·30	32·45
14	54·95	1·172	64·40	21·6	23·3	....	28·7	46·89	24·00	56·45
*15	55·00	1·166	64·13	23·9	25·8	....	31·7	47·17	24·00	80·45
16	55·10	1·166	64·24	21·6	23·3	....	28·7	47·26	24·00	104·45
17	55·70	....	....	....	....	....	....	....	24·00	128·45
18	55·45	1·154	63·99	20·1	21·7	....	26·7	48·05	24·00	152·45
19	55·25	....	....	....	....	....	....	....	24·00	176·45
20	55·20	1·140	62·92	16·8	18·1	....	22·3	48·42	24·00	200·45
21	54·85	....	....	....	....	....	....	....	24·00	224·45
22	54·75	1·120	61·32	15·5	16·7	....	20·6	48·88	24·00	248·45
23	54·65	1·119	61·15	13·2	14·3	....	17·6	48·84	24·00	272·45
24	55·30	....	....	....	....	....	....	....	24·00	296·45
*25	54·90	1·117	61·32	9·7	10·5	....	12·9	49·15	24·00	320·45
26	....	....	....	....	....	....	....	....	11·30	332·15

Resistance Cold, 101. Discoloration, 4.

Woodhouse and Rawson Lamp, No. 31.

(Reduction Factor, 0·94. Resistance Cold, 102.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance, Hot.	Hours.	Total Hours.
1885. May.	55·05	1·182	65·07	18·48	17·28	3·76	20·93	46·57	0·45	0·45
12	55·00	1·182	65·01	19·0	17·9	....	21·7	46·53	8·00	8·45
13	55·10	....	....	20·0	18·8	....	22·7	....	23·30	32·15
14	55·15	1·183	65·24	21·4	20·1	....	24·3	46·62	24·00	56·15
*15	55·25	1·178	65·08	22·6	21·2	....	25·7	46·90	24·00	80·15
16	55·50	1·173	65·10	20·8	19·6	....	23·7	47·31	24·00	104·15
17	55·15	....	....	....	....	....	....	....	24·00	128·15
18	54·85	1·146	62·85	17·9	16·8	....	20·3	47·86	24·00	152·15
19	55·25	....	....	....	....	....	....	....	24·00	176·15
20	55·20	1·139	62·87	15·7	14·8	....	17·9	48·46	24·00	200·15
21	54·90	....	....	....	....	....	....	....	24·00	224·15
22	....	....	....	....	....	....	....	....	3·00	227·15

Carbon broke at side of loop 3.00 A. M., May 22, 1885. Discoloration, 4.

*These lamps, Nos. 30–00 inclusive, were marked 50 volts, but tested at 55.

Woodhouse and Rawson Lamp, No. 32.

(Reduction Factor, 1·07. Resistance Cold, 100.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	55·00	1·195	65·72	16·28	17·36	3·78	21·28	46·02	0·30	0·30
12	54·85	1·177	64·56	18·3	19·6	....	24·1	46·60	8·00	8·30
13	54·95	....	....	16·4	17·5	....	21·5	....	23·30	32·00
14	54·60	1·186	64·75	18·6	19·9	....	24·5	46·04	24·00	56·00
*15	55·00	1·187	65·28	20·6	22·0	....	27·1	46·34	24·00	80·00
16	54·60	1·181	64·48	17·6	18·8	....	23·1	46·23	24·00	104·00
17	55·40	....	....	....	....	....	....	....	24·00	128·00
18	55·00	1·186	65·22	17·5	18·7	....	23·0	46·37	24·00	152·00
19	55·25	....	....	....	....	....	....	....	24·00	176·00
20	55·00	1·184	65·12	15·3	16·4	....	20·2	46·45	24·00	200·00
21	54·95	....	....	....	....	....	....	....	24·00	224·00
22	54·70	1·170	64·00	14·0	15·0	....	18·5	46·75	24·00	248·00
23	54·75	1·168	63·94	12·6	13·5	....	16·6	46·88	24·00	272·00
24	55·45	....	....	....	....	....	....	....	24·00	296·00
*25	55·00	1·169	64·29	11·1	11·9	....	14·6	47·05	24·00	320·00
26	....	....	....	....	....	....	....	....	11·30	331·00

Resistance Cold, 100. Discoloration, 3½.

Woodhouse and Rawson Lamp, No. 33.

(Reduction Factor, 1·00. Resistance Cold, 101.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	55·05	1·188	65·40	19·05	19·01	3·44	22·67	46·43	0·30	0·30
12	55·05	1·175	64·68	18·7	18·7	....	22·3	46·85	7·45	8·15
13	54·95	....	....	18·1	18·1	....	21·5	....	23·30	31·45
14	54·75	1·180	64·60	19·4	19·4	....	23·1	46·40	24·00	55·45
*15	55·00	1·197	65·83	21·5	21·5	....	25·6	45·95	24·00	79·45
16	54·50	1·198	65·29	19·8	19·8	....	23·6	45·49	24·00	103·45
17	55·30	....	....	....	....	....	....	....	24·00	127·45
18	55·10	1·200	66·12	18·8	18·8	....	22·4	45·92	24·00	151·45
19	55·30	....	....	....	....	....	....	....	24·00	175·45
20	55·15	1·195	65·90	17·4	17·4	....	20·7	46·15	24·00	199·45
21	54·95	....	....	....	....	....	....	....	24·00	223·45
22	54·65	1·171	63·99	16·3	16·3	....	19·4	46·67	24·00	247·45
23	54·70	1·170	64·00	14·2	14·2	....	16·9	46·75	24·00	271·45
24	55·50	....	....	....	....	....	....	....	24·00	295·45
*25	55·10	1·169	64·41	11·1	11·1	....	13·2	47·13	24·00	319·45
26	....	....	....	....	....	....	....	....	11·30	331·15

Resistance Cold, 102. Discoloration, 4.

Woodhouse and Rawson Lamp, No. 34.

(Reduction Factor, 1·01 Resistance Cold, 100.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	55·00	1·147	63·08	16·68	16·91	3·73	20·78	47·95	0·30	0·30
12	54·90	1·139	62·53	18·3	18·5	....	22·8	48·20	7·30	8·00
13	54·80	....	....	17·6	17·8	....	21·3	....	23·30	31·30
14	55·00	1·145	62·97	17·9	18·1	....	22·3	48·03	24·00	55·30
*15	55·00	1·139	62·64	21·4	21·6	....	26·6	48·29	24·00	79·30
16	54·85	1·138	62·42	19·0	19·2	....	23·6	48·20	24·00	103·30
17	55·40	....	....	....	....	....	....	....	24·00	127·30
18	55·00	1·134	62·36	18·2	18·4	....	22·6	48·50	24·00	151·30
19	55·30	....	....	....	....	....	....	....	24·00	175·30
20	55·15	1·127	62·15	16·6	16·8	....	20·7	48·94	24·00	199·30
21	54·75	....	....	....	....	....	....	....	24·00	223·30
22	....	....	....	....	....	....	....	....	11·00	234·30

Carbon broke at side of loop near shank 11.00 A. M., May 22, 1885. Discoloration, 3.

Woodhouse and Rawson Lamp, No. 35.

(Reduction Factor, 0·93. Resistance Cold, 101.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	54·95	1·139	62·58	21·14	19·56	3·20	23·53	48.24	0·45	0·45
12	55·00	1·133	62·31	22·0	20·5	....	24·6	48·54	7·30	8·15
13	55·20	....	....	22·2	20·6	....	24·7	....	23·30	31·45
14	54·90	1·117	61·32	22·3	20·7	....	24·8	49·15	24·00	55·45
*15	55·00	1·133	62·31	23·6	21·9	....	26·3	48·54	24·00	79·45
16	55·15	1·107	61·05	22·3	20·7	....	24·8	49·82	24·00	103·45
17	55·05	....	....	....	....	....	....	....	24·00	127·45
18	54·85	1·094	60·00	19·7	18·3	....	21·9	50·14	24·00	151·45
19	55·10	....	....	....	....	....	....	....	24·00	175·45
20	54·95	1·087	59·73	18·3	17·0	....	20·4	50·55	24·00	199·46
21	54·90	....	....	....	....	....	....	....	24·00	223·45
22	54·80	1·071	58·69	16·5	15·3	....	18·4	51·17	24·00	247·45
23	54·95	1·071	58·85	14·4	13·4	....	16·1	51·31	24·00	271·45
24	....	....	....	....	....	....	....	....	0·30	272·15

Carbon broke at side of loop near shank 12.30 A. M., May 24, 1885. Discoloration, 3½.

Woodhouse and Rawson Lamp, No. 36.

(Reduction Factor, 0·97. Resistance Cold, 99.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	55·00	1·191	65·50	22·18	21·41	3·05	25·98	46·18	0·45	0·45
12	54·70	1·180	64·54	23·9	23·2	....	28·1	46·86	7·00	7·45
13	55·15	....	....	22·2	21·5	....	26·0	....	23·30	31·15
14	55·30	1·194	66·02	24·1	23·4	....	28·3	46·82	24·00	55·15
*15	54·85	1·175	64·45	23·9	23·2	....	28·1	46·68	24·00	79·15
16	55·25	1·177	65·03	22·0	21·3	....	25·8	46·94	24·00	103·15
17	55·15	....	....	....	....	....	....	....	24·00	127·15
18	54·95	1·157	63·57	18·1	17·6	....	21·3	47·49	24·00	151·15
19	55·25	....	....	....	....	....	....	....	24·00	175·15
20	54·95	1·149	63·13	15·5	15·0	....	18·2	47·82	24·00	199·15
21	54·85	....	....	....	....	....	....	....	24·00	223·15
22	54·70	1·140	62·35	13·7	13·3	....	16·1	47·98	24·00	247·15
23	54·70	1·137	62·19	12·4	12·0	....	14·5	48·11	24·00	271·15
24	55·46	....	....	....	....	....	....	....	24·00	295·15
*25	55·00	1·135	62·42	9·4	9·1	....	11·0	48·46	24·00	319·15
26	....	....	....	....	....	....	....	....	11·30	330·45

Resistance Cold, 102. Discoloration, 4.

Woodhouse and Rawson Lamp, No. 37.

(Reduction Factor, 1·04. Resistance Cold, 100.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	55·00	1·185	65·17	18·03	18·74	3·47	22·93	46·41	0·30	0·30
12	55·00	1·181	64·95	20·3	21·1	....	25·7	46·57	7·15	7·45
13	55·05	....	....	19·4	20·2	....	24·6	....	23·30	31·15
14	55·00	1·186	65·22	20·4	21·2	....	25·9	46·37	24·00	55·15
*15	55·00	1·180	64·90	20·0	20·8	....	25·4	46·61	24·00	79·15
16	55·25	1·182	65·30	19·5	20·3	....	24·8	46·74	24·00	103·15
17	55·25	....	....	....	....	....	....	....	24·00	127·15
18	55·10	1·165	64·19	17·1	17·8	....	21·7	47·30	24·00	151·15
19	55·30	....	....	....	....	....	....	....	24·00	175·15
20	....	....	....	....	....	....	....	....	1·30	176·45

Carbon broke at side of loop 1.30 A. M., May 20, 1885. Discoloration, 3½.

Woodhouse and Rawson Lamp, No. 38.

(Reduction Factor, 0·99. Resistance Cold, 100.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	54·95	1·197	65·77	18·05	17·84	3·69	20·70	45·91	0·45	0·45
12	54·70	1·194	65·31	18·6	18·4	....	21·3	45·81	7·15	8·00
13	54·80	....	....	19·5	19·3	....	22·4	....	23·30	31·30
14	54·85	1·219	66·86	19·0	18·8	....	21·8	45·00	24·00	55·30
*15	....	1·217	....	19·9	19·7	....	22·9	....	24·00	79·30
16	54·75	1·221	66·85	18·4	18·2	....	21·1	44·84	24·00	103·30
17	54·95	....	....	....	....	....	....	....	24·00	127·30
18	55·20	1·229	67·84	18·6	18·4	....	21·3	44·92	24·00	151·30
19	55·25	....	....	....	....	....	....	....	24·00	175·30
20	55·30	1·220	67·46	17·6	17·4	....	20·2	45·33	24·00	199·30
21	55·10	....	....	....	....	....	....	....	24·00	223·30

Carbon broke at middle of loop 11.55 P. M., May 21, 1885. Discoloration, 4½.

Woodhouse and Rawson Lamp, No. 00.†

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May. 12	54·95	1·151	68·24	20·0	....	....	....	47·74	6·45	6·45
13	55·35	....	....	20·0	....	....	....	....	23·30	30·15
14	55·40	1·150	63·71	19·6	....	....	....	48·17	24·00	54·15
*15	54·95	1·137	62·47	20·1	....	....	....	48·33	24·00	78·15
16	55·05	1·137	62·59	18·4	....	....	....	48·42	24·00	102·15
17	55·65	....	....	....	....	....	....	....	24·00	126·15
18	55·10	1·119	61·65	18·1	....	....	....	49·24	24·00	150·15
19	55·35	....	....	....	....	....	....	....	24·00	174·15
20	54·80	1·093	59·89	15·3	....	....	....	50·14	24·00	198·15
21	....	....	....	....	....	....	....	....	14·15	212·30

Carbon broke at side of loop near shank 2.15 P. M., May 21, 1885. Discoloration, 4.

† Lamp 39 having been disabled before duration test began, this lamp on which no efficiency measurements had been made was substituted for it.

White Lamps, 50 Volts.

White Lamp, No. 1.

(Reduction Factor, 0·85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	1·033	51·65	12·78	10·80	4·78	13·08	48·40	0·45	0·45
13	49·20	1·062	52·25	16·1	13·7	…………	16·6	46·33	12·00	12·45
14	50·05	1·102	55·15	18·5	15·7	…………	19·0	45·42	24·00	36·45
*15	49·90	1·115	55·63	22·6	19·2	…………	23·2	44·75	24·00	60·45
16	49·80	1·122	55·87	20·0	17·0	…………	20·6	44·39	24·00	84·45
17	49·95	…………	…………	…………	…………	…………	…………	…………	24·00	108·45
18	49·60	1·122	55·65	20·5	17·4	…………	21·1	44·21	24·00	132·45
19	50·20	…………	…………	…………	…………	…………	…………	…………	24·00	156·45
20	49·85	1·132	56·43	20·2	17·2	…………	20·2	44·04	24·00	180·45
21	50·20	…………	…………	…………	…………	…………	…………	…………	24·00	204·45
22	49·90	1·132	56·48	19·7	16·7	…………	20·2	44·08	24·00	228·45
23	49·85	1·129	56·28	18·5	15·7	…………	19·0	44·16	24·00	252·45
24	50·10	…………	…………	…………	…………	…………	…………	…………	24·00	276·45
*25	49·90	1·127	56·23	13·8	11·7	…………	14·2	44·28	24·00	300·45
26	…………	…………	…………	…………	…………	…………	…………	…………	11·30	312·15

Resistance Cold, 94. Discoloration, 3½.

White Lamp, No. 2.

(Reduction Factor, 0·85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	1·005	50·25	12·93	10·97	4·58	13·20	49·75	0·30	0·30
13	49·90	1·023	51·04	15·6	13·3	…………	16·0	48·78	11·45	12·15
14	49·85	1·041	51·89	17·5	14·9	…………	17·9	47·89	24·00	36·15
*15	50·25	1·049	52·71	19·8	16·8	…………	20·2	47·90	24·00	60·15
16	49·80	1·057	52·63	19·3	16·4	…………	19·7	47·12	24·00	84·15
17	50·05	…………	…………	…………	…………	…………	…………	…………	24·00	108·15
18	49·75	1·054	52·43	18·3	15·6	…………	18·7	47·20	24·00	132·15
19	49·95	…………	…………	…………	…………	…………	…………	…………	24·00	156·15
20	50·00	1·055	52·75	18·6	15·8	…………	19·0	47·39	24·00	180·15
21	50·10	…………	…………	…………	…………	…………	…………	…………	24·00	204·15
22	50·10	1·052	52·70	17·6	15·0	…………	18·0	47·63	24·00	228·15
23	50·05	1·056	52·85	16·9	14·4	…………	17·3	47·40	24·00	252·15
24	50·15	…………	…………	…………	…………	…………	…………	…………	24·00	276·15
*25	50·10	1·044	52·30	12·8	10·9	…………	13·1	47·99	24·00	300·15
26	…………	…………	…………	…………	…………	…………	…………	…………	11·30	311·45

Resistance Cold, 98. Discoloration, 2½.

White Lamp, No. 3.

(Reduction Factor, 0·85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	·928	46·40	10·75	9·09	4·05	11·08	53·88	0·45	0·45
13	49·95	·949	47·40	13·5	11·5	....	14·0	52·63	10·45	11·30
14	49·75	·969	48·20	15·2	12·9	....	15·7	51·34	24·00	35·30
*15	50·15	·989	49·59	18·2	15·5	....	18·9	50·71	24·00	59·30
16	49·90	·992	49·50	16·6	14·1	....	17·2	50·30	24·00	83·30
17	49·95	....	....	....	....	....	....	....	24·00	107·30
18	50·00	1·001	50·05	16·8	14·3	....	17·4	49·95	24·00	131·30
19	50·05	....	....	....	....	....	....	....	24·00	155·30
20	49·85	·998	49·75	16·4	13·9	....	17·0	49·95	24·00	179·30
21	50·05	....	....	....	....	....	....	....	24·00	203·30
22	49·95	·997	49·80	15·8	13·4	....	16·3	50·10	24·00	227·30
23	50·05	·996	49·84	14·4	12·2	....	14·9	50·25	24·00	251·30
24	50·10	....	....	....	....	....	....	....	24·00	275·30
*25	49·95	·988	49·35	11·6	9·9	....	12·1	50·56	24·00	299·30
26	....	....	....	....	....	....	....	....	11·30	311·00

Resistance Cold, 105. Discoloration, 3.

White Lamp, No. 4.

(Reduction Factor, 0·85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	49·95	1·020	50·95	16·75	14·17	3·59	17·17	48·97	0·15	0·15
13	49·90	1·054	52·59	20·2	17·2	....	20·8	47·34	11·30	11·45
14	49·75	1·079	53·68	21·8	18·5	....	22·4	46·11	24·00	35·45
*15	50·05	1·087	54·40	24·0	20·4	....	24·7	46·04	24·00	59·45
16	50·00	1·087	54·35	22·3	19·0	....	23·0	46·00	24·00	83·45
17	50·20	....	....	....	....	....	....	....	24·00	107·45
18	50·50	1·094	55·24	21·8	18·5	....	22·4	46·16	24·00	131·45
19	50·35	....	....	....	....	....	....	....	24·00	155·45
20	50·10	1·079	54·05	19·4	16·5	....	20·0	46·43	24·00	179·45
21	50·25	....	....	....	....	....	....	....	24·00	203·45
22	50·10	1·068	53·50	18·6	15·8	....	19·1	46·91	24·00	227·45
23	50·20	1·072	53·81	17·5	14·9	....	18·0	46·83	24·00	251·45
24	50·10	....	....	....	....	....	....	....	24·00	275·45
*25	49·95	1·054	52·64	13·2	11·2	....	13·6	47·39	24·00	299·45
26	....	....	....	....	....	....	....	....	11·30	311·15

Resistance Cold, 90. Discoloration, 3.

White Lamp, No. 5.

(Reduction Factor, 0·84.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	·995	49·75	17·00	14·31	3·47	17·05	50·25	0·30	0·30
13	49·95	1·025	51·19	20·0	16·8	……	20·00	48·73	10·30	11·00
14	49·90	1·056	52·69	22·0	18·5	……	22·00	47·25	24·00	35·00
*15	49·70	1·056	52·48	23·9	20·1	……	23·9	47·07	24·00	59·00
16	49·70	1·058	52·58	22·2	18·6	……	22·2	46·98	24·00	83·00
17	49·95	……	……	……	……	……	……	……	24·00	107·00
18	49·80	1·054	52·48	20·2	17·0	……	20·2	47·25	24·00	131·00
19	50·10	……	……	……	……	……	……	……	24·00	155·00
20	50·05	1·044	52·25	17·6	14·8	……	17·6	47·94	24·00	179·00
21	50·00	……	……	……	……	……	……	……	24·00	203·00
22	49·90	1·033	51·54	15·9	13·4	……	16·0	48·30	24·00	227·00
23	50·10	1·031	51·65	14·5	12·2	……	14·5	48·59	24·00	251·00
24	50·35	……	……	……	……	……	……	……	24·00	275·00
*25	50·10	1·023	51·25	11·3	9·5	……	11·3	48·97	24·00	299·00
26	……	……	……	……	……	……	……	……	11·30	810·30

Resistance Cold, 103. Discoloration, 4.

White Lamp, No. 6.

(Reduction Factor, 0·84.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	1·047	52·35	17·38	14·64	3·57	17·55	47·76	0·15	0·15
18	49·65	1·070	53·12	20·3	17·1	……	20·5	46·40	10·15	10·30
14	49·90	1·098	54·79	22·3	18·7	……	22·4	45·45	24·00	34·30
*15	50·20	1·113	55·87	27·1	22·8	……	27·4	45·10	24·00	58·30
16	50·25	1·116	56·07	25·5	21·4	……	25·7	45·03	24·00	82·30
17	49·95	……	……	……	……	……	……	……	24·00	106·30
18	49·80	1·093	54·43	22·0	18·5	……	22·2	45·56	24·00	130·30
19	50·05	……	……	……	……	……	……	……	24·00	154·30
20	49·95	1·086	54·24	19·5	16·4	……	19·7	46·00	24·00	178·30
21	50·10	……	……	……	……	……	……	……	24·00	202·30
22	50·10	1·073	53·75	18·5	15·5	……	18·6	46·69	24·00	226·30
23	……	……	……	……	……	……	……	……	2·00	228·30

Carbon broke at side of loop 2 A.M., May 23, 1885. Discoloration, 4.

White Lamp, No. 7.

(Reduction Factor, 0·85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	1·001	50·05	16·46	13·99	3·57	16·98	49·95	0·30	0·30
13	50·35	1·033	52·01	20·2	17·2	....	20·8	48·74	11·15	11·45
14	50·20	1·043	52·35	21·9	18·6	....	22·5	48·18	24·00	35·45
*15	50·00	1·038	51·90	23·8	20·2	....	24·4	48·17	24·00	59·45
16	50·20	1·040	52·20	20·1	17·1	....	20·7	48·27	24·00	83·45
17	49·95	....	....	....	....	....	....	....	24·00	107·45
18	49·75	1·019	50·69	18·0	15·3	....	18·5	48·82	24·00	131·45
19	50·20	....	....	....	....	....	....	....	24·00	155·45
20	....	....	....	....	....	....	....	....	4·00	159·45

Carbon broke at side of loop 4 A.M., May 20, 1885. Discoloration, 8½.

White Lamp, No. 8.

(Reduction Factor, 0·83.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	1·025	51·25	14·3	11·69	4·38	14·23	48·78	0·15	0·15
13	49·70	1·030	51·19	15·2	12·6	....	15·4	48·25	10·00	10·15
14	49·95	1·056	52·74	17·9	14·9	....	18·2	47·30	24·00	34·15
*15	50·15	1·071	53·71	20·5	17·0	....	20·7	46·83	24·00	58·15
16	49·90	1·073	53·54	19·6	16·3	....	19·9	46·51	24·00	82·15
17	50·00	....	....	....	....	....	....	....	24·00	106·15
18	49·95	1·080	53·94	19·4	16·1	....	19·6	46·25	24·00	130·15
19	50·15	....	....	....	....	....	....	....	24·00	154·15
20	49·75	1·076	53·53	18·3	15·2	....	18·5	46·24	24·00	178·15
21	50·05	....	....	....	....	....	....	....	24·00	202·15
22	49·85	1·075	53·59	18·4	15·3	....	18·7	46·37	24·00	226·15
23	49·90	1·075	53·64	15·8	13·1	....	16·0	46·42	24·00	250·15
24	50·00	....	....	....	....	....	....	....	24·00	274·15
*25	50·05	1·077	53·90	13·5	11·2	....	13·7	46·47	24·00	298·15
26	....	....	....	....	....	....	....	....	11·30	309·45

Resistance Cold, 97. Discoloration, 3.

White Lamp, No. 9.

(Reduction Factor, 0·83.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	50·00	1·206	60·30	15·95	13·22	4·56	15·92	41·46	0·30	0·30
13	50·00	1·214	60·70	18·1	15·0	....	18·0	41·19	11·00	11·30
14	50·20	1·227	61·59	19·9	16·5	....	19·8	40·91	24·00	35·30
*15	49·95	1·224	61·13	19·7	16·4	....	19·7	40·81	24·00	59·30
16	49·95	....	....	19·5	16·2	....	19·4	....	24·00	83·30
17	50·25	....	....	....	....	....	....	....	24·00	107·30
18	49·80	1·222	60·85	18·4	15·3	....	18·4	40·75	24·00	131·30
19	50·10	....	....	....	....	....	....	....	24·00	155·30
20	....	....	....	....	....	....	....	....	9·30	165·00

Carbon broke at middle of loop 9.25 A. M., May 20, 1885. Discoloration, 2½.

White Lamp, No. 10.

(Reduction Factor, 0·81.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	49·95	·908	45·35	14·20	11·55	3·92	14·26	55·01	0·15	0·15
13	49·95	·914	45·65	16·4	13·3	....	16·4	54·65	10·00	10·15
14	49·65	·924	45·87	17·3	14·0	....	11·2	53·73	24·00	34·15
*15	50·05	·935	46·79	19·9	16·1	....	19·8	53·53	24·00	58·15
16	49·90	·931	46·45	18·2	14·7	....	18·1	53·60	24·00	82·15
17	50·20	....	....	....	....	....	....	....	24·00	106·15
18	49·85	·931	46·41	18·3	14·8	....	18·2	53·55	24·00	130·15
19	50·10	....	....	....	....	....	....	....	24·00	154·15
20	49·95	·928	46·35	17·0	13·8	....	17·0	53·83	24·00	178·15
21	50·10	....	....	....	....	....	....	....	24·00	202·15
22	50·10	·921	46·14	16·9	13·7	....	16·9	54·40	24·00	226·15
23	50·20	·922	46·28	14·3	11·6	....	14·3	54·45	24·00	250·15
24	50·00	....	....	....	....	....	....	....	24·00	274·15
*25	50·10	·915	45·84	11·1	9·0	....	11·1	54·76	24·00	298·15
26	....	....	....	....	....	....	....	....	11·30	309·45

Resistance Cold, 114. Discoloration, 3.

WESTON LAMPS, 110½ VOLTS.

Weston Lamp, No. 1.

(Reduction Factor, 0·87.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·3	·519	57·76	20·10	17·49	3·30	19·36	214·5	1·45	1·45
11	....	....	....	17·5	15·2	....	16·9	....	3·45	5·30
12	....	....	....	....	....	....	....	....	24·00	29·30
13	108·4	·458	49·65	10·1	8·8	....	9·8	236·7	24·00	53·30
14	109·8	·458	50·29	11·5	10·0	....	11·1	239·7	24·00	77·30
15	110·6	....	....	....	....	....	....	....	24·00	101·30
16	110·5	·460	50·83	13·6	11·9	....	13·2	240·2	24·00	125·30
17	110·2	·455	50·14	12·1	10·5	....	11·7	242·2	24·00	149·30
18	111·3	....	....	....	....	....	....	....	24·00	173·30
19	110·9	·458	50·79	12·7	11·0	....	12·2	242·1	24·00	197·30
20	110·6	....	....	....	....	....	....	....	20·45	218·15
21	....	....	....	....	....	....	....	....	9·00	227·15

Carbon broke at side of loop 9.00 A. M., April 21. 1885. Discoloration, 2½

Weston Lamp, No. 2.

(Reduction Factor, 0·85.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·0	·530	58·83	16·72	14·16	4·15	15·37	209·4	2·15	2·15
11	....	....	....	16·2	13·8	....	15·0	....	3·45	6·00
12	....	....	....	....	....	....	....	....	24·00	30·00
13	....	....	....	....	....	....	....	....	16·45	46·45

Carbon broke at side of loop at 4.45 P. M., April, 13, 1885. Discoloration, ½.

Weston Lamp, No. 3.

(Reduction Factor, 0·87.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·3	·502	55·87	16·32	14·28	3·82	15·77	221·7	1·00	1·00
11	....	....	....	14·0	12·2	....	13·4	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	108·3	·435	47·11	4·9	4·3	....	4·7	249·0	24·00	52·45
14	111·3	·451	50·19	6·7	5·8	....	6·4	246·8	24·00	76·45
15	110·6	....	....	....	....	....	....	....	24·00	100·45
16	110·6	·444	49·10	3·5	3·0	....	3·3	249·1	24·00	124·45
17	110·3	·446	49·19	6·5	5·7	....	6·3	247·3	24·00	148·45
18	111·4	....	....	....	....	....	....	....	24·00	172·45
19	110·9	·449	49·79	6·7	5·8	....	6·4	247·0	24·00	196·45
20	109·6	....	....	....	....	....	....	....	20·45	217·30
21	110·0	·445	48·95	6·8	5·9	....	6·5	247·2	24·00	241·30
22	110·0	....	....	....	....	....	....	....	24·00	265·30
23	110·5	·446	49·28	6·1	5·3	....	5·8	247·8	24·00	289·30
24	110·1	....	....	....	....	....	....	....	24·00	313·30
*25	110·4	·445	49·23	6·1	5·3	....	5·8	247·5	24·00	337·30
26	110·1	....	....	....	....	....	....	....	21·00	358·30
*27	110·0	·444	48·83	6·4	5·6	....	6·2	247·7	24·00	382·30
*28	110·4	·448	49·46	5·9	5·1	....	5·6	246·4	24·00	406·30
*29	110·6	·448	49·55	5·9	5·1	....	5·6	246·9	24·00	430·30
30	110·4	·451	49·79	7·9	6·9	....	7·6	244·8	24·00	454·30
May.										
1	110·3	·448	49·41	7·5	6·5	....	7·2	246·2	24·00	478·30
2	110·3	·448	49·41	7·0	6·1	....	6·7	246·2	24·00	502·30
3	110·7	....	....	....	....	....	....	....	24·00	526·30
4	110·3	....	....	....	....	....	....	....	24·00	550·30
5	110·5	·451	49·83	7·8	6·8	....	7·5	245·0	24·00	574·30
6	110·4	·448	49·46	7·7	6·7	....	7·4	246·4	23·30	598·00
7	110·2	....	....	....	....	....	....	....	24·00	622·00
8	110·4	....	....	....	....	....	....	....	24·00	646·00
9	110·1	·447	49·21	8·0	7·0	....	7·7	246·3	24·00	670·00
10	110·4	....	....	....	....	....	....	....	24·00	694·00
11	110·4	·450	49·68	7·8	6·8	....	7·5	245·3	24·00	718·00
12	110·4	....	....	....	....	....	....	....	24·00	742·00
13	110·8	....	....	....	....	....	....	....	23·30	765·30
14	110·6	·450	49·77	7·9	6·9	....	7·6	245·8	24·00	789·30
15	110·7	....	....	....	....	....	....	....	24·00	813·30
16	110·1	·449	49·43	7·9	6·9	....	7·6	245·2	24·00	837·30
17	110·6	....	....	....	....	....	....	....	24·00	861·30
18	110·3	·450	49·63	8·5	7·4	....	8·1	245·1	24·00	885·30
19	110·2	·452	49·81	7·3	6·4	....	7·0	243·8	24·00	909·30
20	110·2	....	....	....	....	....	....	....	24·00	933·30
21	110·3	·450	49·63	7·9	6·9	....	7·6	245·1	24·00	957·30
22	110·3	....	....	....	....	....	....	....	24·00	981·30
23	109·9	·448	49·23	7·7	6·7	....	7·4	245·3	24·00	1,005·30
24	110·1	....	....	....	....	....	....	....	24·00	1,029·30
*25	109·9	·449	49·34	6·0	5·2	....	5·7	244·8	24·00	1,053·30
26	....	....	....	....	....	....	....	....	11·30	1,065·00

Resistance Cold, 442. Discoloration 2.

Weston Lamp, No. 4.

(Reduction Factor, 0·78.)

Date.	Volts.	Amperes.	Watts	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles, Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·6	·546	60·93	16·20	12·70	4·79	13·81	204·4	1·30	1·30
11	....	....	....	11·1	8·7	....	9·5	....	3·45	5·15
12	....	....	....	....	....	....	....	....	24·00	29·15
13	108·4	·452	49·00	4·3	3·4	....	3·7	239·8	24·00	53·15
14	110·5	·447	49·39	4·9	3·8	....	4·1	247·2	24·00	77·15
15	110·6	....	....	....	....	....	....	....	24·00	101·15
16	....	....	....	....	....	....	....	....	5·30	106·45

Carbon broke at side of loop 5.30 A. M., April 16, 1885. Discoloration, 1½.

Weston Lamp, No. 5.

(Reduction Factor, 0·88.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·537	59·87	18·18	16·01	3·74	17·53	207·6	0·30	0·30
11	....	....	....	16·6	14·6	....	15·9	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	108·2	·492	53·23	11·0	9·7	....	10·6	219·9	24·00	52·15
14	109·3	·496	54·21	12·2	10·7	....	11·7	220·4	24·00	76·15
15	110·0	....	....	....	....	....	....	....	24·00	100·15
16	110·6	·499	55·19	14·5	12·8	....	14·0	221·6	24·00	124·15
17	110·4	·498	54·98	12·6	11·1	....	12·1	221·7	24·00	148·15
18	111·5	....	....	....	....	....	....	....	24·00	172·15
19	111·3	·500	55·65	13·8	12·1	....	13·2	222·6	24·00	196·15
20	111·0	....	....	....	....	....	....	....	20·45	217·00
21	110·1	·491	54·05	13·6	12·0	....	13·1	224·2	24·00	241·00
22	109·8	....	....	....	....	....	....	....	24·00	265·00
23	110·1	·484	53·28	11·6	10·2	....	11·1	227·5	24·00	289·00
24	110·4	....	....	....	....	....	....	....	24·00	313·00
25	....	....	....	....	....	....	....	....	7·00	320·00

Carbon broke at middle of loop 7.00 A. M., April 25, 1885. Discoloration, 2½.

Weston Lamp, No. 6.

(Reduction Factor, 0·81. Resistance Cold, 402.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles, Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·501	55·86	14·00	11·25	4·96	12·18	222·6	1·15	1·15
11	....	....	....	13·0	10·5	....	11·3	....	3·45	5·00
12	....	....	....	....	....	....	....	....	24·00	29·00
13	108·7	·476	51·74	9·1	7·4	....	8·0	228·4	24·00	53·00
14	109·1	·480	52·37	9·6	7·8	....	8·4	227·3	24·00	77·00
15	110·6	....	....	....	....	....	....	....	24·00	101·00
16	110·9	·490	54·34	11·6	9·4	....	10·2	226·3	24·00	125·00
17	110·3	·492	54·26	11·1	9·0	....	9·7	224·2	24·00	149·00
18	111·3	....	....	....	....	....	....	....	24·00	173·00
19	111·5	·499	55·63	11·1	9·0	....	9·7	223·4	24·00	197·00
20	111·4	....	....	....	....	....	....	....	20·45	217·45
21	110·0	·491	54·01	11·7	9·5	....	10·3	224·0	24·00	241·45
22	109·7	....	....	....	....	....	....	....	24·00	265·45
23	110·8	·498	55·17	10·8	8·7	....	9·4	222·5	24·00	289·45
24	110·7	....	....	....	....	....	....	....	24·00	313·45
*25	110·9	·500	55·44	10·8	8·7	....	9·4	221·8	24·00	337·45
26	110·6	....	....	....	....	....	....	....	21·00	358·45
*27	110·4	·496	54·75	10·8	8·7	....	9·4	222·6	24·00	382·45
*28	110·3	·494	54·48	10·1	8·2	....	8·9	223·3	24·00	406·45
*29	110·4	·497	54·87	10·0	8·1	....	8·7	222·1	24·00	430·45
30	110·4	·499	55·09	13·6	11·8	....	11·9	221·2	24·00	454·45
May.										
1	110·5	·497	54·91	12·3	10·0	....	10·8	222·3	24·00	478·45
2	110·4	·498	54·98	12·6	10·2	....	11·0	221·7	24·00	502·45
3	110·2	....	....	....	....	....	....	....	24·00	526·45
4	110·2	....	....	....	....	....	....	....	24·00	550·45
5	110·5	·496	54·80	13·0	10·5	....	11·3	222·8	24·00	574·45
6	110·2	·496	54·65	12·3	10·0	....	10·8	222·2	23·30	598·15
7	110·1	....	....	....	....	....	....	....	24·00	622·15
8	110·4	....	....	....	....	....	....	....	24·00	646·15
9	109·9	·494	54·29	12·5	10·1	....	10·9	222·5	24·00	670·15
10	110·1	....	....	....	....	....	....	....	24·00	694·15
11	110·7	·498	55·12	12·7	10·3	....	11·1	222·3	24·00	718·15
12	110·4	....	....	....	....	....	....	....	24·00	742·15
13	111·1	....	....	....	....	....	....	....	23·30	765·45
14	110·7	·499	55·24	12·4	10·0	....	10·8	221·8	24·00	789·45
15	110·9	....	....	....	....	....	....	....	24·00	813·45
16	110·8	·502	55·62	13·4	10·9	....	11·8	220·7	24·00	837·45
17	110·8	....	....	....	....	....	....	....	24·00	861·45
18	110·9	·499	55·33	13·7	11·1	....	12·0	222·2	24·00	885·45
19	110·9	·498	55·22	11·7	9·5	....	10·3	222·7	24·00	909·45
20	110·9	....	....	....	....	....	....	....	24·00	933·45
21	110·9	·499	55·33	13·1	10·6	....	11·4	222·2	24·00	957·45
22	110·9	....	....	....	....	....	....	....	24·00	981·45
23	110·6	·495	54·74	12·4	10·0	....	10·8	223·4	24·00	1,005·45
24	110·7	....	....	....	....	....	....	....	24·00	1,029·45
*25	110·6	·494	54·63	9·7	7·9	....	8·5	223·9	24·00	1,053·45
26	....	....	....	....	....	....	....	....	11·30	1,065·15

Resistance Cold, 424. Discoloration, 2.

Weston Lamp, No. 7.

(Reduction Factor, 0·83. Resistance Cold, 414.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·543	60·54	21·95	18·32	3·30	20·10	205·3	0·30	0·30
11	......	......	......	14·0	11·6	......	12·8	......	3·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	109·0	·432	47·09	3·8	3·2	......	3·5	252·3	24·00	52·15
14	109·3	·421	46·01	3·6	3·0	......	3·3	250·6	24·00	76·15
15	110·8	......	......	......	......	......	......	......	24·00	100·15
16	111·2	·412	45·81	2·1	1·8	......	2·0	269·9	24·00	124·15
17	110·7	·406	44·94	3·6	3·0	......	3·3	272·7	24·00	148·15
18	111·3	......	......	......	......	......	......	......	24·00	172·15
19	112·2	·401	44·99	3·8	3·2	......	3·5	279·8	24·00	196·15
20	112·4	......	......	......	......	......	......	......	20·45	217·00
21	110·7	·392	43·39	3·7	3·1	......	3·4	282·4	24·00	241·00
22	110·4	......	......	......	......	......	......	......	24·00	265·00
23	110·7	·391	43·28	3·3	2·7	......	3·0	283·1	24·00	289·00
24	110·7	......	......	......	......	......	......	......	24·00	313·00
*25	110·6	·390	43·13	3·2	2·7	......	3·0	283·6	24·00	337·00
26	110·1	......	......	......	......	......	......	......	21·00	358·00
*27	110·5	·384	42·43	3·4	2·8	......	3·1	287·8	24·00	382·00
*28	110·8	·387	42·88	3·0	2·5	......	2·8	286·3	24·00	406·00
*29	110·5	·385	42·54	2·9	2·4	......	2·6	287·0	24·00	430·00
30	111·0	·387	42·95	4·6	3·8	......	4·2	286·8	24·00	454·00
May.										
1	110·7	·388	42·95	3·8	3·2	......	3·5	285·3	24·00	478·00
2	110·6	·387	42·80	3·7	3·1	......	3·4	285·8	24·00	502·00
3	110·5	......	......	......	......	......	......	......	24·00	526·00
4	111·0	......	......	......	......	......	......	......	24·00	550·00
5	111·0	·389	43·17	4·2	3·5	......	3·9	285·3	24·00	574·00
6	110·0	·383	42·13	3·7	3·1	......	3·4	287·2	23·30	597·30
7	110·4	......	......	......	......	......	......	......	24·00	621·30
8	110·7	......	......	......	......	......	......	......	24·00	645·30
9	110·2	·382	42·09	4·0	3·3	......	3·6	288·5	24·00	669·30
10	110·5	......	......	......	......	......	......	......	24·00	693·30
11	110·5	·382	42·21	3·8	3·2	......	3·5	289·3	24·00	717·30
12	110·4	......	......	......	......	......	......	......	24·00	741·30
13	111·0	......	......	......	......	......	......	......	23·30	765·00
14	110·6	·385	42·58	3·8	3·2	......	3·5	287·3	24·00	789·00
15	111·0	......	......	......	......	......	......	......	24·00	813·00
16	110·3	·383	42·24	4·2	3·5	......	3·9	288·0	24·00	837·00
17	110·7	......	......	......	......	......	......	......	24·00	861·00
18	110·4	·382	42·17	4·1	3·4	......	3·7	289·0	24·00	885·00
19	110·4	·382	42·17	3·5	2·9	......	3·2	289·0	24·00	909·00
20	110·4	......	......	......	......	......	......	......	24·00	933·00
21	110·4	·379	41·84	3·9	3·2	......	3·5	291·3	24·00	957·00
22	110·6	......	......	......	......	......	......	......	24·00	981·00
23	110·2	·379	41·76	3·5	2·9	......	3·2	290·8	24·00	1,005·00
24	110·6	......	......	......	......	......	......	......	24·00	1,029·00
*25	110·5	·379	41·87	2·7	2·2	......	2·4	291·6	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11·30	1,064·30

Resistance Cold, 544. Discoloration, 2.

Weston Lamp, No. 8.

(Reduction Factor, 0·92. Resistance Cold, 423.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885 April.	111·5	·523	58·31	21·88	20·23	2·88	22·54	213·2	0·30	0·30
11	....	....	....	19·5	17·9	....	19·9	....	3·45	4·15
12	....	....	....	....	....	....	....	... ...	24·00	28·15
13	110·0	·458	50·38	10·9	10·0	....	11·1	240·2	24·00	52·15
14	109·9	·454	49·89	10·9	10·0	....	11·1	242·1	24·00	76·15
15	111·0	....	....	....	....	....	....	....	24·00	100·15
16	112·3	·458	51·43	13·0	11·9	....	13·2	245·2	24·00	124·15
17	110·7	·449	49·70	11·1	10·2	....	11·3	246·5	17·00	141·15

Carbon broke at both shanks 5.00 P. M., April 17, 1885. Discoloration, 2½.

Weston Lamp, No. 11.

(Reduction Factor, 0·77. Resistance Cold, 409.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·4	·513	57·14	21·04	16·16	3·53	17·86	217·2	0·30	0·30
11	....	....	....	14·2	10·9	....	12 1	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	110·1	·430	47·34	5·1	3·9	....	4·3	256·0	24·00	52·15
14	110·6	·428	47·33	4·7	3·6	....	4·0	258·4	24·00	76·15
15	111·7	....	....	....	....	....	....	....	24·00	100·15
16	111·7	·413	46·13	2·6	2·0	....	2·2	270·5	24·00	124·15
17	110·7	·403	44·61	3·6	2·8	....	3·1	274·7	24·00	148·15
18	110·5	....	....	....	....	....	....	....	21·00	169·15

Carbon broke at middle of loop 9.00 P. M., April 18, 1885. Discoloration, 1½.

Weston Lamp, No. 9.

(Reduction Factor, 0·75. Resistance Cold, 409.

Date.	Volts.	Amperes	Watts.	Candles.		Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
				Observed.	Spherical.					
1885. April.	111·4	·530	59·04	21·90	16·53	3·57	17·97	210·2	0·30	0·30
11	...	...	...	15·0	11·3	...	12·3	...	3·45	4·15
12	...	...	...	...	...	...	...	...	24·00	28·15
13	110·5	·457	50·50	7·0	5·3	...	5·8	241·8	24·00	52·15
14	110·1	·455	50·09	7·5	5·7	...	6·2	242·0	24·00	76·15
15	110·9	...	...	...	...	...	...	...	24·00	100·15
16	112·1	·467	52·35	9·6	7·2	...	7·8	240·0	24·00	124·15
17	110·9	·460	51·01	8·1	6·1	...	6·6	241·1	24·00	148·15
17	110·8	...	...	...	...	...	...	...	24·00	172·15
19	111·7	·462	51·60	8·3	6·2	...	6·8	241·8	24·00	196·15
20	111·4	...	...	...	...	...	...	...	20·45	217·00
21	109·8	·456	50·06	8·2	6·2	...	6·8	240·8	24·00	241·00
22	109·7	...	...	...	...	...	...	...	24·00	265·00
23	110·2	·453	49·92	7·4	5·6	...	6·1	243·3	24·00	289·00
24	110·2	...	...	...	...	...	...	...	24·00	313·00
*25	110·5	·456	50·38	7·4	5·6	...	6·1	242·3	24·00	337·00
26	110·2	...	...	...	...	...	...	...	21·00	358·00
*27	109·7	·454	49·80	7·4	5·6	...	6·1	241·6	24·00	382·00
*28	110·7	·456	50·47	6·9	5·2	...	5·7	242·8	24·00	406·00
*29	110·4	·457	50·45	7·1	5·8	...	5·8	241·6	24·00	430·00
30	110·3	·456	50·29	10·2	7·7	...	8·4	241·9	24·00	454·00
May.										
1	110·4	·455	50·23	8·5	6·4	...	7·0	242·6	24·00	478·00
2	110·3	·457	50·40	8·5	6·4	...	7·0	241·4	24·00	502·00
3	110·6	...	...	...	...	...	...	...	24·00	526·00
4	110·4	...	...	...	...	...	...	...	24·00	550·00
5	110·7	·459	50·81	8·9	6·7	...	7·3	241·2	24·00	574·00
6	110·6	·456	50·43	8·6	6·5	...	7·1	242·6	23·30	597·30
7	110·4	...	...	...	...	...	...	...	24·00	621·30
8	110·4	...	...	...	...	...	...	...	24·00	645·30
9	110·2	·455	50·14	9·3	7·0	...	7·6	242·2	24·00	669·30
10	110·5	...	...	...	...	...	...	...	24·00	693·30
11	110·4	·457	50·45	8·9	6·7	...	7·3	241·6	24·00	717·30
12	110·1	...	...	...	...	...	...	...	24·00	741·30
13	111·0	...	...	...	...	...	...	...	23·30	765·00
14	110·5	·458	50·60	9·2	6·9	...	7·5	241·3	24·00	789·00
15	110·7	...	...	...	...	...	...	...	24·00	813·00
16	110·2	·458	50·47	9·7	7·3	...	8·0	240·6	24·00	837·00
17	110·8	...	...	...	...	...	...	...	24·00	861·00
18	110·3	·457	50·40	10·1	7·6	...	8·3	241·4	24·00	885·00
19	110·3	·457	50·40	8·3	6·2	...	6·8	241·4	24·00	909·00
20	110·3	...	...	...	...	...	...	...	24·00	933·00
21	110·4	·455	50·23	9·5	7·1	...	7·7	242·6	24·00	957·00
22	110·6	...	...	...	...	...	...	...	24·00	981·00
23	110·1	·454	49·98	8·4	6·3	...	6·9	242·5	24·00	1,005·00
24	110·2	...	...	...	...	...	...	...	24·00	1,029·00
*25	110·1	·455	50·09	6·9	5·2	...	5·7	242·0	24·00	1,053·00
26	...	...	...	...	...	...	...	...	11·30	1,064·30

Resistance Cold, 455. Discoloration, 2.

Weston Lamp, No. 10.

(Reduction Factor, 0·86. Resistance Cold, 421.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·529	58·98	22·15	19·08	3·09	20·82	210·8	0·15	0·15
11	....	....	....	17·0	14·6	....	15·9	....	3·45	4·00
12	....	....	....	....	....	....	....	....	24·00	28·00
13	110·5	·476	52·60	9·3	8·0	....	8·7	232·1	24·00	52·00
14	111·0	·477	52·95	9·9	8·5	....	9·3	232·7	24·00	76·00
15	111·5	....	....	....	....	....	....	....	24·00	100·00
16	111·9	·488	54·60	12·0	10·4	....	11·3	229·3	24·.0	124·00
17	111·0	·482	53·50	10·6	9·1	....	9·9	230·3	24·00	148·00
18	110·4	....	....	....	....	....	....	....	24·00	172·00
19	111·7	·485	54·17	10·6	9·1	....	9·9	230·3	24·00	196·00
20	111·5	....	....	....	....	....	....	....	20·45	216·45
21	109·6	·480	52·61	10·5	9·0	....	9·8	228·3	24·00	240·45
22	109·9	....	....	....	....	....	....	....	24·00	264·45
23	110·4	·478	52·77	10·0	8·6	....	9·4	231·0	24·00	288·45
24	110·4	....	....	....	....	....	....	....	24·00	312·45
*25	109·8	·480	52·70	10·2	8·8	....	9·6	228·7	24·00	336·45
26	110·5	....	....	....	....	....	....	....	21·00	357·45
*27	110·1	·479	52·73	10·0	8·6	....	9·4	229·9	24·00	381·45
*28	110·2	·480	52·89	9·0	7·7	....	8·4	229·6	24·00	405·45
*29	110·0	·478	52·58	9·1	7·8	....	8·5	230·1	24·00	429·45
30	110·0	·481	52·91	13·2	11·4	....	12·4	228·7	24·00	453·45
May.						....				
1	109·9	·479	52·64	11·7	10·1	....	11·0	229·4	24·00	477·45
2	110·0	·478	52·58	11·4	9·8	....	10·7	230·1	24·00	501·45
3	110·5	....	....	....	....	....	....	....	24·00	525·45
4	110·4	....	....	....	....	....	....	....	24·00	549·45
5	110·3	·480	52·94	12·2	10·5	....	11·4	229·8	24·00	573·45
6	110·2	·477	52·56	11·4	9·8	....	10·7	231·0	23·30	597·15
7	110·1	....	....	....	....	....	....	....	24·00	621·15
8	110·4	....	....	....	....	....	....	....	24·00	645·15
9	110·0	·477	52·47	12·4	10·7	....	11·7	230·6	24·00	669·15
10	109·8	....	....	....	....	....	....	....	24·00	693·15
11	110·6	·480	53·08	12·4	10·7	....	11·7	230·4	24·00	717·15
12	111·0	....	....	....	....	....	....	....	24·00	741·15
13	111·3	....	....	....	....	....	....	....	23·30	764·45
14	110·5	·477	52·70	11·6	10·0	....	10·9	231·7	24·00	788·45
15	110·9	....	....	....	....	....	....	....	24·00	812·45
16	....	....	....	....	....	....	....	....	10·30	823·15

Carbon broke at side of loop 10.35 A. M., May 16, 1885. Discoloration, 2.

Weston Lamp, No. 12.

(Reduction Factor, 0·87. Resistance Cold, 408.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·553	61·66	25·68	22·26	2·77	24·45	201·6	0·30	0·30
11	....	....	....	16·4	14·3	....	15·7	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	109·7	·497	54·52	14·9	12·9	4·22	14·2	220·7	24·00	52·15
14	110·1	·493	54·28	15·5	13·5	....	14·8	223·8	24·00	76·15
15	....	....	....	....	....	....	....	....	5·00	81·15

Carbon broke at middle of loop 5.00 A. M., April 15, 1885. Discoloration, 2.

Weston Lamp, No. 13.

(Reduction Factor, 0·80. Resistance Cold, 407.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·531	59·20	20·30	16·27	3·63	18·18	210·0	0·30	0·30
11	....	....	....	15·0	12·0	....	13·3	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	110·0	·453	49·83	6·9	5·5	9·06	6·1	242·8	24·00	52·15
14	110·4	·453	50·01	6·8	5·4	....	6·0	243·7	24·00	76·15
15	111·6	....	....	....	....	....	....	....	24·00	100·15
16	111·7	·458	51·15	8·4	6·7	....	7·4	243·9	24·00	124·15
17	111·1	·455	50·55	7·5	6·0	....	6·7	244·2	24·00	148·15
18	110·7	....	....	....	....	....	....	....	24·00	172·15
19	112·0	·450	51·40	7·5	6·0	....	6·7	244·0	24·00	196·15
20	112·5	....	....	....	....	....	....	....	20·45	217·00
21	110·4	·450	49·68	7·5	6·0	....	6·7	245·3	24·00	241·00
22	110·1	....	....	....	....	....	....	....	14·30	255·30

Carbon broke at shank 2.30 P. M., April 22, 1885. Discoloration, 2.

Weston Lamp, No. 14.

(Reduction Factor, 0·78. Resistance Cold, 409.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·4	·549	61·15	24·65	19·14	3·19	21·31	202·9	0·30	0·30
11	....	....	....	16·0	12·5	....	18·9	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	109·9	·439	48·25	4·9	3·8	....	4·2	250·3	24·00	52·15
14	110·5	·432	47·74	4·8	3·7	....	4·1	255·8	24·00	76·15
15	112·1	....	....	....	....	....	....	....	24·00	100·15
16	111·7	·419	46·80	2·5	2·0	....	2·2	266·6	24·00	124·15
17	111·5	·412	45·93	4·0	3·1	....	3·4	270·6	24·00	148·15
18	110·5	....	....	....	....	....	....	....	24·00	172·15
19	111·8	·404	45·16	3·6	2·8	....	3·1	276·7	24·00	196·15
20	111·6	....	....	....	....	....	....	....	16·15	212·30

Carbon broke at middle of loop 7.30 P. M., April 20, 1885. Discoloration, 1.

Weston Lamp, No. 15.

(Reduction Factor, 0·82. Resistance Cold, 408.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·4	·491	54·69	11·97	9·78	5·59	10·45	226·9	1·00	1·00
11	....	....	....	10·4	8·5	....	9·1	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	109·9	·449	49·35	6·0	4·9	....	5·2	244·8	24.00	52·45
14	111·0	·453	50·28	7·1	5·8	....	6·2	245·0	24·00	76·45
15	111·6	....	....	....	....	....	....	....	24·00	100·45
16	111·1	·452	50·21	8·2	6·7	....	7·2	245·8	24·00	124·45
17	110·8	·455	50·41	7·1	5·8	....	6·2	243·5	24·00	148·45
18	110·5	....	....	....	....	....	....	....	24·00	172·45
19	111·0	·454	50·39	7·0	5·7	....	6·1	244·5	20·15	193·00

Carbon broke at shank 8.15 P. M., April 19, 1885. Discoloration, 1.

Weston Lamp, No. 16.

(Reduction Factor, 0·83. Resistance Cold, 399.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot	Hours.	Total Hours.
1885. April.	111·4	·518	57·14	18·12	15·08	3·80	16·43	217·2	0·30	0·30
11	......	......	......	16·4	13·6	......	14·8	......	3·45	4·15
12	......	......	......	......	......	......	......	......	24·00	28·15
13	108·7	·505	54·89	13·7	11·4	......	12·4	215·3	24·00	52·15
14	110·4	·515	56·85	16·2	13·4	......	14·6	214·4	24·00	76·15
15	110·3	......	......	......	......	......	......	......	24·00	100·15
16	110·9	·516	57·22	20·0	16·6	......	18·1	214·9	24·00	124·15
17	110·6	·516	57·07	16·9	14·0	......	15·3	214·3	24·00	148·15
18	110·4	......	......	......	......	......	......	......	24·00	172·15
19	110·8	·514	56·95	16·7	13·9	......	15·2	215·6	24·00	196·15
20	110·6	......	......	......	......	......	......	......	20·45	217·00
21	110·4	·515	56·85	17·0	14·1	......	15·4	214·4	24·00	241·00
22	109·6	......	......	......	......	......	......	......	24·00	265·00
23	110·6	·511	56·51	14·7	12·2	......	13·3	216·4	24·00	289·00
24	110·5	......	......	......	......	......	......	......	24·00	313·00
*25	110·6	·508	56·18	13·9	11·5	......	12·5	217·7	24·00	337·00
26	110·5	......	......	......	......	......	......	......	21·00	358·00
*27	110·3	·501	55·26	13·6	11·3	......	12·3	220·2	24·00	382·00
*28	110·7	·501	55·46	12·2	10·1	......	11·0	221·0	24·00	406·00
*29	110·8	·500	55·40	12·1	10·0	......	10·9	221·6	24·00	430·00
30	111·0	·498	55·27	16·4	13·6	......	14·8	222·9	24·00	454·00
May.										
1	110·8	·498	55·17	14·4	12·0	......	13·1	222·5	24·00	478·00
2	110·9	·497	55·11	14·3	11·9	......	13·0	223·1	24·00	502·00
3	110·6	......	......	......	......	......	......	......	24·00	526·00
4	110·4	......	......	......	......	......	......	......	24·00	550·00
5	110·4	·487	53·76	13·8	11·5	......	12·5	226·7	24·00	574·00
6	110·4	·489	53·98	12·8	10·6	......	11·6	225·8	23·30	597·30
7	110·2	......	......	......	......	......	......	......	24·00	621·30
8	110·6	......	......	......	......	......	......	......	24·00	645·30
9	110·1	·481	52·95	13·1	10·9	......	11·9	228·9	24·00	669·30
10	110·4	......	......	......	......	......	......	......	24·00	693·30
11	110·3	·483	53·27	12·5	10·4	......	11·3	228·4	24·00	717·30
12	110·2	......	......	......	......	......	......	......	24·00	741·30
13	111·0	......	......	......	......	......	......	......	23·30	765·00
14	110·5	·480	53·04	12·0	10·0	......	10·9	230·2	24·00	789·00
15	110·7	......	......	......	......	......	......	......	24·00	813·00
16	110·3	·480	52·94	12·5	10·4	......	11·3	229·8	24·00	837·00
17	110·7	......	......	......	......	......	......	......	24·00	861·00
18	110·3	·475	52·39	12·7	10·5	......	11·4	232·2	24·00	885·00
19	110·4	·474	52·33	10·7	8·9	......	9·7	232·9	24·00	909·00
20	110·5	......	......	......	......	......	......	......	24·00	933·00
21	110·4	·472	52·10	11·6	9·6	......	10·5	233·9	24·00	957·00
22	110·3	......	......	......	......	......	......	......	24·00	981·00
23	110·1	·470	51·74	10·7	8·9	......	9·7	234·3	24·00	1,005·00
24	110·4	......	......	......	......	......	......	......	24·00	1,029·00
*25	110·4	·468	51·66	8·5	7·1	......	7·7	235·9	24·00	1,053·00
26	......	......	......	......	......	......	......	......	11·30	1,064·30

Resistance Cold, 457. Discoloration, 3.

Weston Lamp, No. 17.

(Reduction Factor, 0·80. Resistance Cold, 404.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·5	·521	58·09	15·35	12·23	4·75	14·08	214·0	1·00	1·00
11	....	....	....	10·6	8·5	....	9·8	....	3·45	4·45
12	....	....	....	....	....	....	....	....	24·00	28·45
13	....	....	....	....	....	....	....	....	11·45	40·30

Carbon broke at shank at 11.45 A. M., April 13, 1885. Discoloration, ½.

Weston Lamp, No. 19.

(Reduction Factor, 0·73. Resistance Cold, 402.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·4	·561	62·49	27·95	20·30	3·07	22·98	198·6	0·30	0·30
11	....	....	....	20·2	14·7	....	16·6	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	109·8	·491	53·91	13·7	10·0	5·39	11·3	223·6	24·00	52·15
14	....	....	....	....	....	....	....	....	12·45	65·00

Carbon broke at side of loop at 12.45 P. M., April 14, 1885. Discoloration, 2.

Weston Lamp, No. 18.

(Reduction Factor, 0·80. Resistance Cold, 405.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Mean Horizontal Candles.	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·4	·540	60·15	20·97	16·71	3·60	17·95	206·3	0·30	0·30
11	....	....	....	13·6	10·9	....	11·7	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	109·6	·448	49·10	4·6	3·7	....	4·0	244·6	24·00	52·15
14	111·4	·451	50·24	5·0	4·0	....	4·8	247·0	24·00	76·15
15	111·1	....	....	....	....	....	....	....	24·00	100·15
16	112·3	·441	49·52	2·8	2·2	....	2·4	254·6	24·00	124·15
17	110·5	·431	47·62	5·0	4·0	....	4·3	256·4	24·00	148·15
18	111·5	....	....	....	....	....	....	....	24·00	172·15
19	111·7	·433	48·36	5·5	4·4	....	4·7	258·0	24·00	196·15
20	112·1	....	....	....	....	....	....	....	20·45	217·00
21	111·6	·432	48·21	5·9	4·7	....	5·0	258·3	24·00	241·00
22	110·8	....	....	....	....	....	....	....	24·00	265·00
23	110·9	·423	46·91	4·5	3·6	....	3·9	262·2	24·00	289·00
24	110·0	....	....	....	....	....	....	....	24·00	313·00
*25	110·7	·426	47·15	4·5	3·6	....	3·9	259·9	24·00	337·00
26	110·7	....	....	....	....	....	....	....	21·00	358·00
*27	110·3	·421	46·43	4·7	3·8	....	4·1	262·0	24·00	382·00
*28	110·6	·425	47·00	4·0	3·2	....	3·4	260·2	24·00	406·00
*29	110·5	·425	46·96	4·5	3·6	....	3·9	260·0	24·00	430·00
30	110·6	·424	46·89	6·3	5·0	....	5·4	260·9	24·00	454·00
May.										
1	110·4	·423	46·69	5·5	4·4	....	4·7	261·0	24·00	478·00
2	110·5	·422	46·63	5·3	4·2	....	4·5	261·8	24·00	502·00
3	110·3	....	....	....	....	....	....	....	24·00	526·00
4	110·3	....	....	....	....	....	....	....	24·00	550·00
5	110·5	·423	46·74	5·6	4·5	....	4·8	261·2	24·00	574·00
6	110·3	·420	46·32	5·4	4·3	....	4·7	262·6	23·30	597·30
7	110·2	....	....	....	....	....	....	....	24·00	621·30
8	110·7	....	....	....	....	....	....	....	24·00	645·30
9	110·0	·419	46·08	5·5	4·4	....	4·7	262·5	24·00	669·30
10	110·4	....	....	....	....	....	....	....	24·00	693·30
11	110·3	·420	46·32	5·4	4·3	....	4·6	262·6	24·00	717·30
12	110·2	....	....	....	....	....	....	....	24·00	741·30
13	110·9	....	....	....	....	....	....	....	23·30	765·00
14	110·5	·421	46·52	5·4	4·3	....	4·6	262·5	24·00	789·00
15	110·6	....	....	....	....	....	....	....	24·00	813·00
16	110·2	·421	46·39	5·5	4·4	....	4·7	261·8	24·00	837·00
17	110·8	....	....	....	....	....	....	....	24·00	861·00
18	110·2	·419	46·17	5·8	4·6	....	4·9	263·0	24·00	885·00
19	110·2	·421	46·39	5·0	4·0	....	4·3	261·8	24·00	909·00
20	110·3	....	....	....	....	....	....	....	24·00	933·00
21	110·3	·417	45·99	5·5	4·4	....	4·7	264·5	24·00	957·00
22	110·3	....	....	....	....	....	....	....	24·00	981·00
23	109·9	·415	45·60	5·2	4·2	....	4·5	264·8	24·00	1,005·00
24	110·1	....	....	....	....	....	....	....	24·00	1,029·00
*25	110·0	·418	45·98	4·0	3·2	....	3·4	263·2	24·00	1,053·00
26	....	....	....	....	....	....	....	....	11·30	1,064·30

Resistance Cold, 488. Discoloration, 2.

Weston Lamp, No. 20.

(Reduction Factor, 0·90. Resistance Cold, 392.)

Date.	Volts.	Ampères.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles, Mean Horizontal	Resistance Hot.	Hours.	Total Hours.
1885. April.	111·4	·562	62·60	21·68	19·44	3·22	20·88	198·2	0·30	0·30
11	....	....	....	12·1	10·9	....	11·7	....	3·45	4·15
12	....	....	....	....	....	....	....	....	24·00	28·15
13	109·9	·488	53·63	7·7	6·9	....	7·4	225·2	24·00	52·15
14	111·3	·495	55·10	8·2	7·4	....	7·9	224·8	24·00	76·15
15	110·6	....	....	....	....	....	....	....	24·00	100·15
16	112·2	·502	56·32	11·2	10·0	....	10·7	223·5	24·00	124·15
17	111·9	·499	55·83	10·3	9·3	....	10·0	224·2	24·00	148·15
18	111·4	....	....	....	....	....	....	....	24·00	172·15
19	111·1	·491	54·55	9·5	8·6	....	9·2	226·3	24·00	196·15
20	112·0	....	....	....	....	....	....	....	20·45	217·00
21	111·0	·496	55·05	9·9	8·9	....	9.5	223·8	24·00	241·00
22	110·1	....	....	....	....	....	....	....	24·00	265·00
23	109·9	·484	53·19	8·2	7·4	....	7·9	227·1	24·00	289·00
24	109·9	....	....	....	....	....	....	....	24·00	313·00
*25	110·0	·491	54·01	8·3	7·5	....	8·0	224·0	24·00	337·00
26	109·9	....	....	....	....	....	....	....	21·00	358·00
*27	109·9	·490	53·85	8·8	7·9	....	8·5	224·3	24·00	382·00
*28	110·5	·491	54·25	7·7	6·9	....	7·4	225·1	24·00	406·00
*29	110·5	·493	54·47	8·1	7·3	....	7·8	224·1	24·00	430·00
30	110·6	·493	54·52	11·5	10·4	....	11·1	224·3	24·00	454·00
May.										
1	110·4	·490	54·09	10·0	9·0	....	9·6	225·3	24·00	478·00
2	110·6	·494	54·63	9·8	8·8	....	9·4	223·9	24·00	502·00
3	110·4	....	....	....	....	....	....	....	24·00	526·00
4	110·3	....	....	....	....	....	....	....	24 00	550·00
5	110·5	·494	54·58	10·5	9·5	....	10·2	223·7	24·00	574·00
6	110·4	·489	53·98	9·7	8·7	....	9·3	225·8	23·30	597·30
7	110·2	....	....	....	....	....	....	....	24·00	621·30
8	110·4	....	....	....	....	....	....	....	24·00	645·30
9	110·0	·487	53·57	10·6	9·5	....	10·2	225·9	24·00	669·30
10	110·3	....	....	....	....	....	....	....	24·00	693·30
11	110·1	·489	53·83	10·3	9·3	....	10·0	225·2	24·00	717·30
12	110·8	....	....	....	....	....	....	....	24·00	741·30
13	110·9	....	....	....	....	....	....	....	23·30	765·00
14	110·4	·490	54·09	10·2	9·2	....	9·8	225·3	24·00	789·00
15	110·6	....	....	....	....	....	....	....	24·00	813·00
16	110·0	·490	53·90	10·7	9·6	....	10·3	224·5	24·00	837·00
17	110·4	....	....	....	....	....	....	....	24·00	861·00
18	110·0	·488	53·68	11·1	10·0	....	10·7	225·4	24·00	885·00
19	110·5	·490	54·14	9·6	8·6	....	9·2	225·5	24·00	909·00
20	110·7	....	....	....	....	....	....	....	24·00	933·00
21	110·8	·489	54·18	10·8	9·7	....	10·4	226·6	24·00	957·00
22	110·8	....	....	....	....	....	....	....	24·00	981·00
23	110·4	·486	53·65	10·6	9·5	....	10·2	227·2	24·00	1,005·00
24	110·1	....	....	....	....	....	....	....	24·00	1,029·00
*25	110·3	·484	53·38	7·9	7·1	....	7·6	227·9	24·00	1,053·00
26	....	....	....	....	....	....	....	....	11·30	1,064·30

Resistance Cold not measured. Discoloration, 2.

Weston Lamps, 70 Volts

Weston Lamp, No. 51.

(Reduction Factor, 0·84· Resistance Cold, 152.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean. Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·2	·963	67·60	17·35	14·53	4·65	16·22	72·90	0·30	0·30
4	70·0	·951	66·57	16·8	14·1	....	15·8	73·61	9·00	9·30
5	70·2	·938	65·84	16·3	13·7	....	15·3	74·84	24·00	33·30
6	69·7	·922	64·26	14·3	12·0	....	13·4	75·60	23·30	57·00
7	70·1	·911	63·86	13·4	11·3	....	12·7	76·95	24·00	81·00
8	71·0	....	....	....	....	....	....	....	24·00	105·00
9	70·6	·891	62·00	12·7	10·7	....	12·0	79·24	24·00	129·00
10	70·5	....	....	....	....	....	....	....	24·00	153·00
11	69·9	·864	60·39	10·1	8·5	....	9·5	80·90	24·00	177·00
12	70·3	....	....	....	....	....	....	....	24·00	201·00
13	70·9	....	....	....	....	....	....	....	23·30	224·30
14	69·7	·833	58·06	8·8	7·4	....	8·3	83·67	24·00	248·30
15	....	....	....	....	....	....	....	....	11·00	259·30

Carbon broke at shank 11.00 A. M., May 15, 1885. Discoloration, 2½.

Weston Lamp, No. 54.

(Reduction Factor, 0·83. Resistance Cold, 149·0.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·4	·959	67·51	17·33	14·46	4·66	15·73	73·41	0·45	0·45
4	70·3	·948	66·64	16·5	13·7	....	14·9	74·16	9·00	9·45
5	69·9	·944	65·98	16·4	13·6	....	14·8	74·05	24·00	33·45
6	....	·942	....	15·4	12·8	....	14·0	....	23·30	57·15
7	70·0	·946	66·22	16·1	13·4	....	14·6	74·00	24·00	81·15
8	70·2	....	....	....	....	....	....	....	24·00	105·15
9	69·9	·948	66·26	17·8	14·8	....	16·1	73·74	24·00	129·15
10	70·1	....	....	....	....	....	....	....	24·00	153·15
11	70·0	·952	66·64	18·6	15·4	....	16·8	73·53	24·00	177·15
12	69·8	....	....	....	....	....	....	....	24·00	201·15
13	69·6	....	....	....	....	....	....	....	23·30	224·45
14	70·1	·954	66·87	16·7	13·9	....	15·2	73·48	24·00	248·45
*15	70·0	·951	66·57	18·4	15·3	....	16·7	73·61	24·00	272·45
16	70·0	·953	66·71	17·5	14·5	....	15·8	73·45	24·00	296·45
17	70·4	....	....	....	....	....	....	....	24·00	320·45
18	69·8	·951	66·38	17·5	14·5	....	15·6	73·40	24·00	344·45
19	69·9	....	....	....	....	....	....	....	24·00	368·45
20	69·9	·951	66·47	17·2	14·3	....	15·4	73·50	24·00	392·45
21	70·1	....	....	....	....	....	....	....	24·00	416·45
22	69·8	·948	66·17	17·0	14·1	....	14·4	73·63	24·00	440·45
23	69·8	·949	66·24	15·5	12·9	....	14·1	73·55	24·00	464·45
24	70·0	....	....	....	....	....	....	....	24·00	488·45
*25	69·9	·952	66·54	12·7	10·5	....	11·4	73·43	24·00	512·45
26	....	....	....	....	....	....	....	....	11·30	524·15

Resistance Cold, 148. Discoloration, 2.

Weston Lamp, No. 55.

(Reduction Factor, 0·82. Resistance Cold, 144.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·4	1·002	70·54	20·30	17·11	4·12	18·33	70·26	0·15	0·15
4	70·0	·988	69·16	19·9	16·3	....	17·9	70·85	8·45	9·00
5	70·0	·974	68·18	19·7	16·2	....	17·8	71·87	24·00	33·00
6	....	·975	....	17·5	14·4	....	15·8	....	23·30	56·30
7	69·9	·971	67·87	18·6	15·3	....	16·8	71·99	24·00	80·30
8	70·1	....	....	....	....	....	....	....	24·00	104·30
9	69·8	·972	67·84	19·5	16·0	....	17·6	71·81	24·00	128·30
10	70·1	....	....	....	....	....	....	....	24·00	152·30
11	69·9	·975	68·15	18·7	15·3	....	16·8	71·69	24·00	176·30
12	70·0	....	....	....	....	....	....	....	24·00	200·30
13	69·9	....	....	....	....	....	....	....	23·30	224·00
14	70·1	·972	68·13	18·7	15·3	....	16·8	72·12	24·00	248·00
*15	69·9	·974	68·08	20·6	16·9	....	18·6	71·77	24·00	272·00
16	70·0	·977	68·39	19·5	16·0	....	17·6	71·65	24·00	296·00
17	70·3	....	....	....	....	....	....	....	24·00	320·00
18	69·9	·974	68·08	20·1	16·5	....	18·2	71·77	24·00	344·00
19	69·9	....	....	....	....	....	....	....	24·00	368·00
20	69·9	·972	67·94	19·6	16·1	....	17·7	71·91	24·00	392·00
21	70·3	....	....	....	....	....	....	....	24·00	416·00
22	69·9	·969	67·73	18·8	15·4	....	16·9	72·14	24·00	440·00
23	70·0	·971	67·97	18·1	14·8	....	16·3	72·09	24·00	464·00
24	70·0	....	....	....	....	....	....	....	24·00	488·00
*25	70·0	·969	67·83	14·4	11·8	....	13·0	72·24	24·00	512·00
26	....	....	....	....	....	....	....	....	11·30	523·30

Resistance Cold, 147. Discoloration, 2.

Weston Lamp, No. 56.

(Reduction Factor, 0·83. Resistance Cold, 148.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·4	·969	68·21	18·10	15·07	4·52	16·96	72·65	0·15	0·15
4	69·8	·953	66·52	17·4	14·4	....	16·3	73·24	8·45	9·00
5	69·8	·955	66·65	18·4	15·3	....	17·3	73·09	24·00	33·00
6	....	·955	....	17·4	14·4	....	16·3	....	23·30	56·30
7	69·9	·960	67·10	18·2	15·1	....	17·1	72·81	24·00	80·30
8	70·0	....	....	....	....	....	....	....	24·00	104·30
9	69·7	·962	67·05	19·3	16·0	....	18·1	72·45	24·00	128·30
10	69·9	....	....	....	....	....	....	....	24·00	152·30
11	69·8	·967	67·49	18·4	15·3	....	17·3	72·18	24·00	176·30
12	69·8	....	....	....	....	....	....	....	24·00	200·30
13	69·8	....	....	....	....	....	....	....	23·30	224·00
14	70·0	·966	67·62	17·8	14·8	....	16·7	72·46	24·00	248·00
*15	69·9	·964	67·38	20·2	16·8	....	19·0	72·51	24·00	272·00
16	69·8	·964	67·28	19·3	16·0	....	18·1	72·41	24·00	296·00
17	70·1	....	....	....	....	....	....	....	24·00	320·00
18	69·7	·965	67·26	19·2	15·9	....	18·0	72·23	24·00	344·00
19	69·8	....	....	....	....	....	....	....	24·00	368·00
20	69·9	·965	67·45	18·7	15·5	....	17·5	72·44	24·00	392·00
21	70·2	....	....	....	....	....	....	....	24·00	416·00
22	69·8	·960	67·00	18·5	15·4	....	17·4	72·71	24·00	440·00
23	69·9	·962	67·24	16·6	13·8	....	....	72·66	24.00	464·00
24	70·0	....	....	....	....	....	....	....	24·00	488·00
*25	70·0	·964	67·48	13·9	11·5	....	15·6	72·61	24·00	512·00
26	....	....	....	....	....	....	....	....	11·30	523·30

Resistance Cold, 147. Discoloration, 2.

Weston Lamp, No. 58.

(Reduction Factor, 0·86. Resistance Cold, 153.)

Date.	Volts.	Amperes.	Watts.	Candles. Obrseved.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·5	·952	67·11	19·80	16·95	3·96	18·67	74·05	0·30	0·30
4	69·9	·937	65·49	19·0	16·3	....	17·9	74·60	8·30	9·00
5	69·9	·942	65·84	19·8	17·0	....	18·7	74·21	24·00	33·00
6	69·9	·939	65·63	18·6	16·0	....	17·6	74·44	23·30	56·30
7	69·8	·934	65·19	18·8	16·2	....	17·8	74·73	24·00	80·30
8	69·9	....	....	....	....	....	....	....	24·00	104·30
9	69·9	·935	65·35	19·6	16·9	....	18·6	74·76	24·00	128·30
10	70·1	....	....	....	....	....	....	....	24·00	152·30
11	70·1	·935	65·54	18·4	15·8	....	17·4	74·97	24·00	176·30
12	70·0	....	....	....	....	....	....	....	24·00	200·30
13	70·3	....	....	....	....	....	....	....	23·30	224·00
14	70·4	·934	65·75	18·1	15·6	....	17·2	75·37	24·00	248·00
*15	69·6	·924	64·31	18·9	16·3	....	17·9	75·33	24·00	272·00
16	69·7	·926	64·54	18·2	15·7	....	17·3	75·27	24·00	296·00
17	70·1	....	....	....	....	....	....	....	24·00	320·00
18	69·7	·924	64·40	18·2	15·7	....	17·3	75·43	24·00	344·00
19	69·9	....	....	....	....	....	....	....	24·00	368·00
20	69·9	·921	64·37	17·7	15·2	....	16·7	75·90	24·00	392·00
21	70·1	....	....	....	....	....	....	....	24·00	416·00
22	69·8	·919	64·14	17·6	15·1	....	16·6	75·95	24·00	440·00
23	69·9	·917	64·09	15·4	13·2	....	14·5	76·23	24·00	464·00
24	70·0	....	....	....	....	....	....	....	24·00	488·00
*25	70·0	·915	64·05	12·9	11·1	....	12·2	76·50	24·00	512·00
26	....	....	....	....	....	....	....	....	11·30	523·30

Resistance Cold, 155. Discoloration, 2½.

Weston Lamp, No. 59.

(Reduction Factor, 0·81. Resistance Cold, 152.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885.	70·4	·944	66·45	19·78	16·04	4·14	18·12	74·58	0·15	0·15
May. 4	69·9	·937	65·49	19·4	15·7	......	17·7	74·60	8·15	8·30
5	70.0	·924	64·68	17·6	14·3	......	16·2	75·76	24·00	32·30
6	70.0	·924	64·68	17·5	14·2	......	16·0	75·76	23·30	56·00
7	69·9	·922	64·44	18·3	14·8	......	16·7	75·81	24·00	80·00
8	70·2	......	......	......	......	......	......	......	24·00	104·00
9	69·9	·922	64·44	19·1	15·5	......	17·5	75·81	24·00	128·00
10	70·1	......	......	......	......	......	......	......	24·00	152·00
11	70·1	·905	63·44	18·5	15·0	......	17·0	77·46	24·00	176·00
12	70·3	......	......	......	......	......	......	......	24·00	200·00
13	70·3	......	......	......	......	......	......	......	22·30	222·30

Carbon broke at side of loop near shank 11.00 P. M., May 13, 1885. Discoloration, 2½.

Weston Lamp, No. 61.

(Reduction Factor, 0·84. Resistance Cold, 153.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885.	70·3	·969	68·12	15·48	13·06	5·21	14·23	72·55	0·30	0·30
May. 4	70·0	·960	67·20	16·4	13·8	......	15·0	72·92	8·15	8·45
5	70·1	·956	67·01	16·6	13·9	......	15·0	73·33	24·00	32·45
6	70·0	·959	67·13	14·8	12·4	......	13·5	72·99	23·30	56·15
7	69·8	·956	66·73	15·3	12·9	......	14·0	73·01	24·00	80·15
8	69·9	......	......	......	......	......	......	......	24·00	104·15
9	69·5	·960	66·71	15·6	13·1	......	14·8	72·40	24·00	128·15
10	69·9	......	......	......	......	......	......	......	24·00	152·15
11	70·3	·974	68·47	16·1	13·5	......	14·7	72·18	24·00	176·15
12	70·0	......	......	......	......	......	......	......	24·00	200·15
13	70·4	......	......	......	......	......	......	......	23·30	223·45
14	70·0	·972	68·04	14·7	12·3	......	13·4	72·02	24·00	247·45
*15	70·1	·974	68·27	18·5	15·5	......	16·9	71·97	24·00	271·45
16	70·0	·972	68·04	16·3	13·7	......	14·9	72·02	24·00	295·45
17	70·1	......	......	......	......	......	......	......	24·00	319·45
18	69·7	·972	67·74	16·8	14·1	......	15·4	71·71	24·00	343·45
19	69·9	......	......	......	......	......	......	......	24·00	367·45
20	69·7	·972	67·74	15·7	13·2	......	14·4	71·71	24·00	391·45
21	70·0	......	......	......	......	......	......	......	24·00	415·45
22	69·6	·969	67·44	15·5	13·0	......	14·2	71·83	24·00	439·45
23	69·6	·969	67·44	14·5	12·2	......	13·3	71·83	24·00	463·45
24	70·2	......	......	......	......	......	......	......	24·00	487·45
*25	70·1	·980	68·69	12·3	10·3	......	11·2	71·53	24·00	511·45
26	......	......	......	......	......	......	......	......	11·30	523·15

Resistance Cold, 147. Discoloration, 2.

Weston Lamp, No. 62.

(Reduction Factor, 0·80. Resistance Cold, 148.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles. Mean Horizontal	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·4	·971	68·35	18·02	14·42	4·74	16·03	72·50	0·15	0·15
4	69·7	·960	66·91	16·6	13·3	......	14·8	72·60	8·15	8·30
5	69·9	·938	65·56	12·0	9·6	......	10·7	74·52	24·00	32·30
6	69·9	·934	65·28	11·5	9·2	......	10·2	74·84	23·30	56·00
7	69·9	·928	64·86	11·6	9·3	......	10·3	75·32	24·00	80·00
8	69·9	......	......	......	......	......	......	......	24·00	104·00
9	69·8	·930	64·91	12·4	9·9	......	11·0	75·06	24·00	128·00
10	70·1	......	......	......	......	......	......	......	24·00	152·00
11	70·1	·934	65·47	11·9	9·5	......	10·5	75·05	24·00	176·00
12	70·1	......	......	......	......	......	......	......	24·00	200·00
13	70·0	......	......	......	......	......	......	......	23·30	223·30
14	70·1	·936	65·61	11·6	9·3	......	10·3	74·89	24·00	247·30
*15	70·1	·934	65·47	13·8	11·0	......	12·2	75·05	24·00	271·30
16	69·9	·933	65·21	12·6	10·1	......	11·2	74·92	24·00	295·30
17	70·2	......	......	......	......	......	......	......	24·00	319·30
18	69·7	·932	64·96	13·1	10·5	......	11·7	74·78	24·00	343·30
19	69·9	......	......	......	......	......	......	......	24·00	367·30
20	69·9	·933	65·21	13·2	10·6	......	11·8	74·92	24·00	391·30
21	70·1	......	......	......	......	......	......	......	24·00	415·30
22	69·9	·931	65·07	12·6	10·1	......	11·2	75·08	24·00	439·30
23	69·7	·931	64·89	12·0	9·6	......	10·2	74·87	24·00	463·30
24	69·9	......	......	......	......	......	......	......	24·00	487·30
*25	69·8	·932	65·05	11·3	9·0	......	10·0	74·89	24·00	511·30
26	......	......	......	......	......	......	......	......	11·30	523·00

Lamp adjusted May 5, 1885. Resistance Cold, 152. Discoloration, 2.

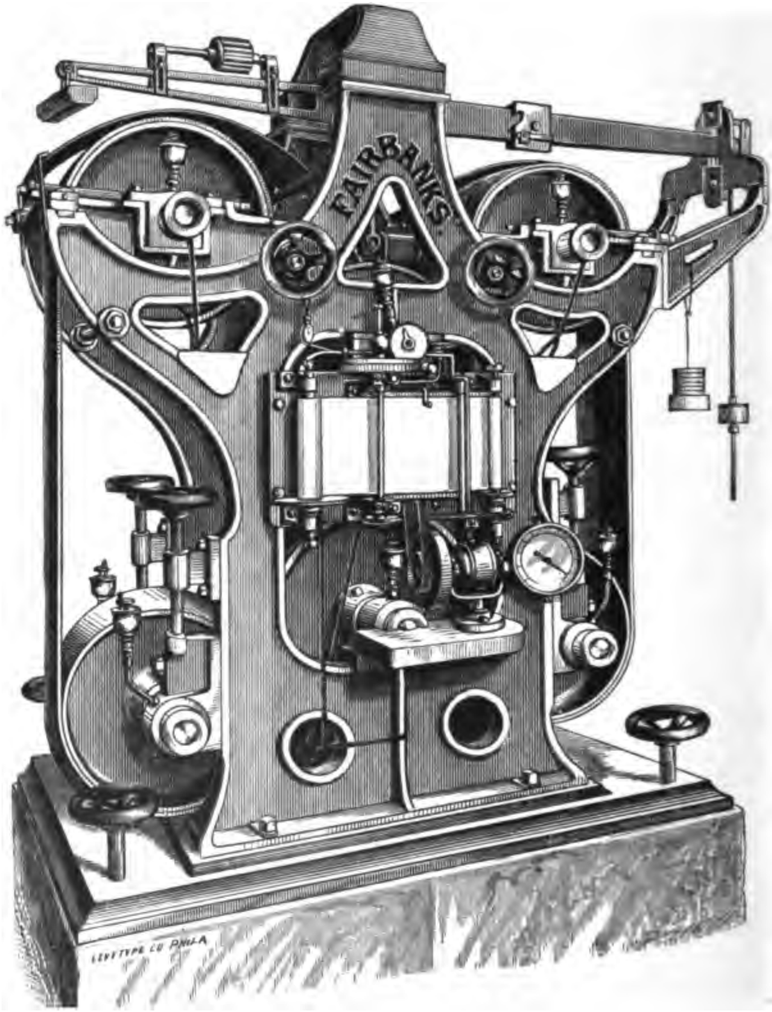
Weston Lamp, No. 63.

(Reduction Factor, 0·81 Resistance Cold, 147.)

Date.	Volts.	Amperes.	Watts.	Candles. Observed.	Candles. Spherical.	Watts per Spher. Cand.	Candles Mean Horizontal.	Resistance Hot.	Hours.	Total Hours.
1885. May.	70·4	·984	69·27	18·35	14·85	4·66	16·93	71·54	0·15	0·15
4	69·7	·965	67·26	16·7	13·5	....	15·4	72·23	8·00	8·15
5	69·9	·966	67·52	16·4	13·3	....	15·2	72·36	24·00	32·15
6	69·7	·960	66·91	16·2	13·1	....	14·9	72·60	23·30	55·45
7	70·0	·966	67·62	16·8	13·6	....	15·5	72·46	24·00	79·45
8	70·0	....	....	....	....	....	....	....	24·00	103·45
9	69·8	·974	67·98	17·4	14·1	....	16·1	71·66	24·00	127·45
10	70·1	....	....	....	....	....	....	....	24·00	151·45
11	69·9	·981	68·57	17·3	14·0	....	16·0	71·25	24·00	175·45
12	69·8	....	....	....	....	....	....	....	24·00	199·45
13	70·0	....	....	....	....	....	....	....	23·30	223·15
14	69·9	·981	68·57	16·7	13·5	....	15·4	71·25	24·00	247·15
*15	70·0	·982	68·74	19·7	16·0	....	18·2	71·28	24·00	271·15
16	69·7	·982	68·44	17·6	14·3	....	16·3	70·98	24·00	295·15
17	70·0	....	....	....	....	....	....	....	24·00	319·15
18	69·8	·984	68·68	19·2	15·6	....	17·8	70·94	24·00	343·15
19	69·9	....	....	....	....	....	....	....	24·00	367·15
20	69·9	·985	68·85	18·6	15·1	....	17·2	70·97	24·00	391·15
21	70·1	....	....	....	....	....	....	....	24·00	415·15
22	69·7	·982	68·44	18·4	14·9	....	17·0	70·98	24·00	439·15
23	69·8	·984	68·68	17·0	13·8	....	15·7	70·94	24·00	463·15
24	69·9	....	....	....	....	....	....	....	24·00	487·15
*25	69·7	·985	68·65	13·6	11·0	....	12·5	70·76	24·00	511·15
26	....	....	....	....	....	....	....	....	11·30	522·45

Resistance Cold, 145. Discoloration, 1½.

Jour. Frank. Inst., Vol. CXX. Nov., 1885.
(Tests of Dynamo-Electric Machines.)



THE TATHAM DYNAMOMETER.

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA
FOR THE
PROMOTION OF THE MECHANIC ARTS.

Competitive Tests
OF
Dynamo-Electric Machines.

Report of a Special Committee, appointed by the President of the Franklin Institute in conformity with a Resolution of the Board of Managers, passed November 12, 1884.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, NOVEMBER, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1885.

EDITING COMMITTEE.

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COLEMAN SELLERS,
WILLIAM H. WAHL.

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA.
FOR THE PROMOTION OF THE MECHANIC ARTS.

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I herewith transmit the report of the Committee of Judges, consisting of Louis Duncan, Ph.D., Ensign, U. S. Navy, Chairman; William D. Marks, Whitney Professor of Dynamic Engineering, University of Pennsylvania; George L. Anderson, Lieut. U. S. Army, Instructor of Mathematics, U. S. Military Academy, West Point; J. B. Murdock, Lieut. U. S. Navy; A. B. Wyckoff, Lieut. U. S. Navy, Hydrographic Office, Philadelphia, appointed under authority of the resolution of the Board, adopted November 12, 1884, to Conduct Competitive Tests of Dynamo-Electric Machines, entered for competition by the Edison Electric Light Company, and the United States Electric Light Company, who duly accepted them as judges.

It was found impossible to constitute the committee from the list of names in the adopted code, most of those gentlemen declining to serve, or accepting under unavailable conditions.

Commander Jewell, U. S. Navy, acted as Chairman at the beginning, and rendered valuable assistance and advice in the preliminary preparations. Owing to unavoidable delays, however, the tests were not begun before his paramount duties at the U. S. Torpedo Station compelled him to withdraw.

The conditions of the code were severe upon the judges, requiring protracted runs of the machines, and immediate calculations of results. The labors of the committee were therefore incessant, and were performed with such zeal, intelligence, fidelity, and success as to satisfy me that no praise of mine could exceed that to which a careful examination of the report of their work will entitle them.

The thanks of the INSTITUTE are due not only to the judges, but also to the heads of the Departments and Bureaus of the Navy and Army, whose consent was necessary to enable the officers to take part in the work.

The INSTITUTE is under especial obligations to the Johns Hopkins University for the use of their laboratory and for assistance in comparing thermometers and resistances.

The thanks of the INSTITUTE are also due to various parties for loans of apparatus, as follows:

Baldwin Locomotive Works, for use of boiler; Buckeye Engine Company, Salem, O., for steam engine; Professors Genth and Sadtler and the department of Dynamics of the University of Pennsylvania, for platinum crucibles, indicators, resistance coils and galvanometer; U. S. Coast and Geodetic Survey, for magnetometer; Stevens Institute of Technology for tangent galvanometer; Mr. Wm. Harpur, for chronometer; Mr. Henry Trœmner, for delicate balances; Messrs. Fairbanks & Co., for beam, platform scales and standard weights; Electrical Supply Company, of New York, for voltameter; Commander Jewell, U. S. Navy, and the members of the committee, for the use of their instruments.

Very respectfully,

W. P. TATHAM, *President.*

PHILADELPHIA, September 26, 1885.

RESOLUTION.

[RESOLUTIONS OF THE BOARD OF MANAGERS, NOV. 22, 1884.]

WHEREAS, Through delay and lack of time on the part of many of the Examiners, several of the largest exhibits at the Electrical Exhibition have had either incomplete examination or have had none at all; therefore, be it

Resolved, That the President be directed to take such steps, appoint such committees, and incur such expense, not exceeding three thousand dollars, as shall be necessary to complete in a satisfactory manner the examination of exhibits.

MR. W. P. TATHAM, *President of the* FRANKLIN INSTITUTE.

SIR:—I have the honor to herewith transmit the report of the Committee appointed to conduct the Competitive Tests of the Dynamo Electric Machines of the U. S. Electric Light and Edison Companies.

I am, very respectfully yours,

LOUIS DUNCAN, *Chairman.*

COMPETITIVE TESTS OF DYNAMO-MACHINES.

On first organizing the committee, Commander Jewell, U. S. N. was elected Chairman, but after directing some of the preliminaries, he was compelled to resign in order to resume his duties at the U. S. Torpedo Station, at Newport.

The tests were conducted under the following code, agreed to by the contestants:

Proposed Code for Test of Dynamo Electric Machines, to be used by the FRANKLIN INSTITUTE *of the State of Pennsylvania.*

SECTION I.

GENERAL CLAUSES AND CONDITIONS.

(1.) The parties hereto subscribing do agree to accept the services of the examiners herein named, and to abide by the verdict of the Judges and the methods of testing named without appeal from the decision reached.

LIST OF JUDGES.

(*From which five shall be chosen to act.*)

(2.) Prof. WM. A. ANTHONY, Cornell University, Ithaca, N. Y.
Prof. WM. D. MARKS, University of Pennsylvania, Philadelphia, Pa.
Prof. J. E. DENTON, Stevens Institute, Hoboken, N. J.
Prof. W. E. GEYER, Stevens Institute, Hoboken, N. J.
Lieut. J. B. MURDOCK, U. S. N., Philadelphia, Pa.
Ensign LOUIS DUNCAN, U. S. N., Johns Hopkins University.
Lieut. JOHN MILLISS, Light-House Board, New York.
OSCAR BUSSMANN, Assistant.

(3.) The FRANKLIN INSTITUTE will procure instruments, pay expenses of observers. The companies will pay for handling machines, running lines, placing and erecting lamps, and care for machines during test.

SECTION II.

CONSTRUCTION OF THE MACHINE.

(4.) The following data will also be given:
Diameter of armature:
Weight of machine;
Number of commutator bars;
Turns and length of wire in armature coils;
Whether brushes must be adjusted, or are automatic for different currents;
Diameter and length of bearings;
Number of turns per minute;
Number of volts for best work;
Number of ampères for best work.

SECTION III.

PRELIMINARY TESTS.

(5.) The resistance of the field magnet coils and of the armature coils will be measured as follows: A strong current from a secondary battery shall be passed through these coils and ampère-meter and sensitive voltameter used to determine current and fall of potential. The resistance will be determined from these measurements. As an additional precaution, a strip of german silver of known resistance shall have its fall of potential measured with the same current and instruments. These measurements shall be made before and after the tests, with the machine hot and cold.

INSULATION RESISTANCE.

(6.) Tests will be made of the insulation of the terminals of the machine from its metal bed-plate.

Tests will be made of the insulation resistance between the commutator and the axle.

(7.) It is understood between the parties that if any mechanical defect is observed, another machine may be substituted if the committee agree that such defect exists.

The competitors shall have reasonable opportunity to obtain information of the progress of the tests, and to know the figures of each test for the object of ascertaining errors in time for correction.

The observations made will be publicly posted before the machine is removed from the dynamometer.

CALIBRATION OF INSTRUMENTS.

(8.) The constants of all instruments used shall be determined by at least two independent methods. The companies shall have opportunity to inspect and observe the methods used and shall be furnished with the constants of the instruments immediately after they have been determined. All objections to the methods used will be received and acted upon as provided under Section IV., Article 17.

SECTION IV.

QUANTITATIVE TESTS.

(9.) The dynamo to be tested will be run under full load for ten hours continuously, to see that all is in good working order before the tests begin.

(10.) For the actual test the machine shall be run and the temperatures of the pole pieces and armatures observed until a uniform temperature is reached.

(11.) When a uniform temperature for each load is reached, the measurements of power shall begin.

(12.) The machine will be tested on both live and dead resistances.

(13.) The machine will be tested on one-quarter, one-half, three-fourths, and full load. In the latter case, to be run at least five hours after a uniform temperature is reached.

(14.) Full measurements of friction and of energy expended in field will be made in each case.

DYNAMOMETRIC MEASUREMENTS.

(15.) The shaft of the dynamo will be directly attached to the end of the shaft of Tatham's dynamometer, by means of a universal joint coupling, and the horse-power used read from the dynamometer, unless the committee, for reason, shall decide otherwise.

OBSERVATIONS.

(16.) The observations on the dynamometer, current galvanometer, and potential galvanometer, and all other instruments, will be taken at synchronous intervals.

The temperature of the room will be made as even as possible, and the temperature noted and necessary corrections made.

The adjustment and oiling of machines shall be in the hands of the authorized expert for the company.

(17.) In case any objection be made, or difference of opinion should arise between the committee and the contestants, the unanimous vote of the committee shall be final.

If, however, there be not a unanimous vote, the minority of the committee shall appoint one referee and the majority another; these two shall appoint a third referee.

The decision of the majority of these referees shall be final.

In all determinations of efficiency of machines, measurement of potential shall be made (simultaneously with measurements of the current strength) at the binding posts of the machine, and at such other points of the circuit as will determine the total fall of potential, due to the resistance of the leads, connections and switches included in circuit with the instruments used for determining current strength. From these measurements, the loss shall be calculated and credited to the machine under trial.

[Signed] FRANCIS R. UPTON.

United States Electric Lighting Company,
per EDWARD WESTON, *Electrician.*

Plate I gives the general arrangement of the apparatus. The test room, in which most of the instruments for electrical measurement were placed, was in about the middle of the Exhibition Building of the FRANKLIN INSTITUTE. The dynamos, with the boiler and engine used in running them, were in a shed at one corner of the building; and the resistances for their external circuit, —lamps and german silver strips—in a room inside the building and very near the shed.

The storage battery, tangent galvanometer for current calibrations, and galvanometer for measuring field currents, were in different parts of the building, far enough from the test room not to affect the instruments in it.

The leads from the dynamos and storage battery, and to the tangent galvanometer were of heavy, insulated copper cable. They were taken to the corner of the test house farthest from the instruments, and where they approached it the two parts of a circuit were twisted together, one of them being covered with rubber tubing as an additional precaution against leakage. Even with the heaviest currents (about 400 ampères) there was no effect on the instruments, and calibrations made both when the dynamos were and were not running, showed that any disturbance from currents in the leads had been avoided.

Before any measurements were made, the insulation resistances between the leads themselves, and from the leads to the ground, were carefully tested and found in every case to be over fifty megohms; and measurements at intervals during the tests showed that they remained about the same.

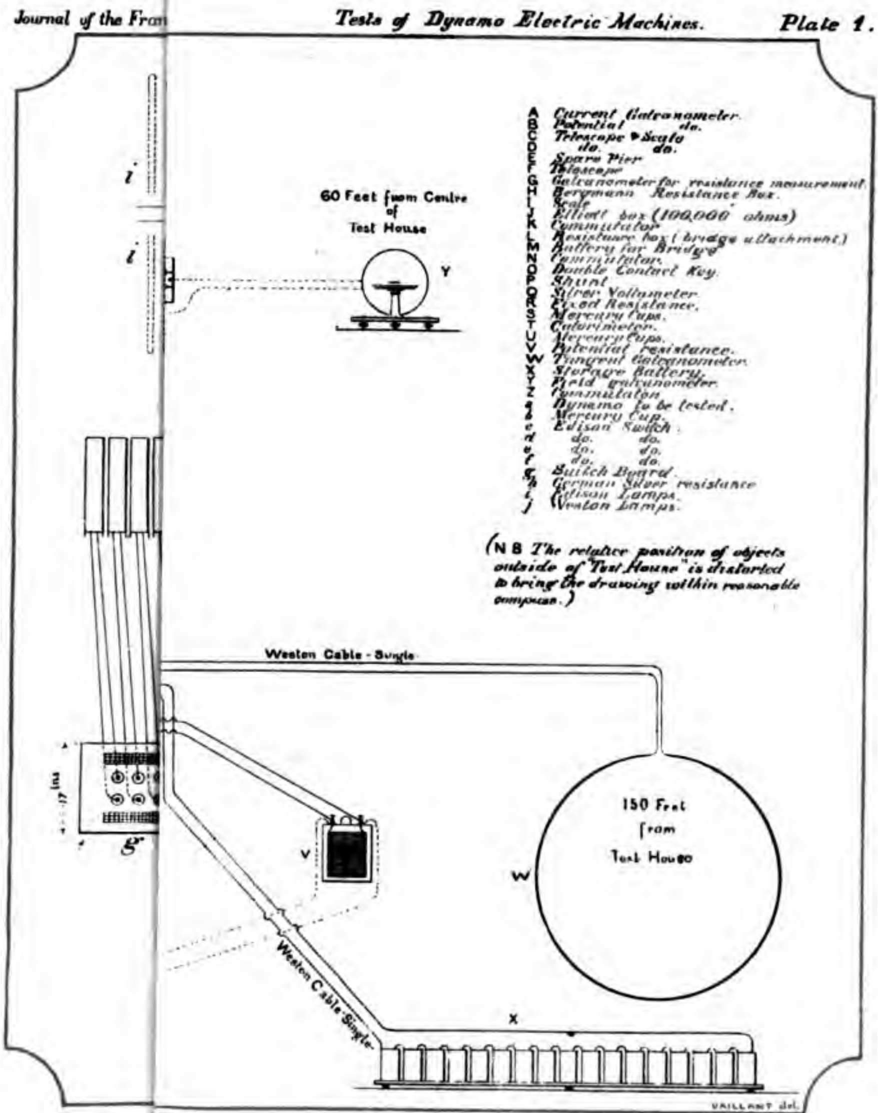
OBSERVATIONS.

The power applied to the dynamos was measured by a Tatham dynamometer, while the electrical energy was calculated from observations of the potential at the terminals of the machine, the currents in the external circuit and field, and the resistance of the armature. The latter was measured by sending a current from a storage battery through the armature and observing the current in the circuit and fall of potential between the terminals of the machine.

The dynamos were run both on lamps and dead resistance, the value of the latter serving as a rough check on the potential and current.

APPARATUS.

Storage Battery.—This was kindly furnished by Mr. Weston, and was used for all calibrations, measurements of armature resistance, etc. Seventeen cells in series were generally employed; they were placed on boards separated from the floor by porcelain insulators.


Journal of the Fran
Tests of Dynamo Electric Machines.
Plate 1.
A Current Galvanometer.
B Potential do.
C Telescope & Scale
D do. do.
E Spare Pier
F Telescope
G Galvanometer for resistance measurement
H Bergmann Resistance Box.
I Scale
J Elliott box (100,000 ohms)
K Commutator
L Resistance box (bridge attachment)
M Battery for Bridge
N Commutator.
O Double Contact Key.
P Shunt
Q Silver Voltameter
R Fixed Resistance.
S Mercury Cups.
T Calorimeter.
U Mercury Cups.
V Potential resistance.
W Tangent Galvanometer.
X Storage Battery.
Y Field galvanometer.
Z Commutator
a Dynamo to be tested.
b Mercury Cup.
c Edison Switch
d do. do.
e do. do.
f do. do.
g Switch Board.
h German Silver resistance
i Edison Lamps.
j Weston Lamps.
(N B The relative position of objects outside of "Test House" is distorted to bring the drawing within reasonable compass.)
60 Feet from Centre of Test House
Y
i
i
Weston Cable - Single
150 Feet from Test House
W
V
X
g
Weston Cable Single
VAILLANT del.

Tangent Galvanometer.—This was used for calibrating the current galvanometer. It consisted of a single turn of large-sized wire fastened on the edge of a wooden disk which was nailed against a square board frame. The ends of the wire were bent up parallel to each other and fastened by brass connectors to the leads. A correction due to the space between the ends of the turn was applied to the mean radius.

The diameter, about two metres, was measured in different directions, and the mean taken in calculating the constant.

There was a space cut in the middle of the wooden frame, with a shelf for the compass and needle. After the needle was adjusted to the centre and levelled, plumb lines and pointers were arranged so that any warping or change of level could be at once detected.

The value of H was determined by a magnetometer of the Coast Survey pattern with detached theodolite; it was found to be

$$\cdot 1938$$

and the constant of the galvanometer;

$$31\cdot 088 \text{ ampères.}$$

External Resistances of Dynamos.—The "dead" resistances for the external circuit of the dynamos were made of german silver strips 1¼ inches wide by about ·01 inch thick. They were eight in number, each wound on a frame about 3 feet square by 10 feet high, made of four wooden uprights with pieces framed across at the top and bottom Porcelain insulators were fastened horizontally to the cross pieces and the resistances passed under one of the bottom insulators, over one at the top, to the bottom again, etc. Heavy copper wires were hard soldered to the ends of the strips and taken to the switch board.

The resistances were adjusted by cutting out part of the strip by a short length of german silver with clamps at the ends, which could be shifted to cut out as many of the turns as was desired. The coils were adjusted by means of a calibrated bridge, to 2·400 ohms at 20° C. There was a good air circulation in the room and fifty ampères could be carried by each coil.

In the same room with the german silver resistances were the racks for the incandescent lamps used for "live" resistances.

Switch-Board.—Two troughs about 2½ feet long and 1½ inches wide, and 10 inches apart, were cut in a heavy block of wood. Between them were bored two rows of eight holes each, and into these

were fitted glass insulators turned upside down to serve as mercury cups. The wood was soaked in boiling paraffine, and melted paraffine poured between the cups and allowed to harden. The distance between the troughs and the middle of the nearest row of cups was three and a-half inches; between the two rows, and the cups in each row, three inches. The cups and troughs were filled with mercury, heavy amalgamated copper rods in the latter serving to increase the conductivity. The resistances were brought to opposite cups in the two rows.

The dynamo circuit was from one terminal of the machine to an ordinary Edison switch, by which the current could be made or broken, to one of the troughs; through the resistance to the other trough; to the test house, passing through the fixed resistance for current measurement there; back by the other lead to the dynamo.

Connections at the switch board were made by thick U-shaped copper rods, with a stretch of three and one-half inches. The resistances could be readily arranged in any desired way, with little or no chance of causing accident by making mistakes. The insulation between the troughs and the cups and the troughs themselves was practically perfect.

Field Galvanometer.—The current in the field of the dynamos was measured by a tangent galvanometer of the Helmholtz type, the coils being each a single turn of large-sized wire. It was calibrated at the same time as the current galvanometer, being reversed as often as possible, and the same end of the needle read on each side of the zero mark.

Wheatstone Bridge.—For measuring resistances that could not be taken to the Johns Hopkins University, a resistance box, with a bridge attachment by Elliott, of London, was used, with a Thomson astatic mirror galvanometer. The box was standardized, as described below.

Calorimeter.—The calorimeter is shown in *Figs. 1 and 2.*

This was used for calibrating both the potential and current galvanometers; it was made of copper, was cylindrical in shape, about 8 inches in diameter by 10 inches in height, and held about eighteen pounds of water.

The cover was screwed to a flange on the cylinder, the joint being water-tight; in it were holes with raised flanges around

them, for the terminals of the coil and the thermometer. For stirring, a shaft, working in a bearing on the bottom of the cylinder and passing through the cover, had on it five paddles arranged along its length and at different angles around it, and bent to throw the water past the wire out to the side of the vessel. On reaching the side, a downward motion was given to it by strips of light copper, making an angle of about 30° with the vertical, soldered to the cylinder and projecting inward one and one-fourth inches. On the bottom of the shaft was a propeller blade. Putting saw-dust on the water and turning the shaft slowly showed the circulation to be excellent. Turning the wheel belted to the pulley on the shaft three times per second, raised the temperature of the calorimeter ·02° C. in five minutes. In the later experiments it was only turned once per second, so the error from this correction must have been small.

In the first three experiments, copper wire of about 1·3 ohms resistance was used; in the last two, platinum-silver wire of 1·1 ohms. The coil was held in the cylinder as follows: At equal distances around the cylinder, at the top and bottom, were soldered pieces of copper projecting inward, with clamps at their ends. The wire was wound on glass rods held in a light framework; the whole was placed in the cylinder, the rods clamped in place and the framework cut away, leaving a clear space for the stirring arrangement.

The terminals were small copper cups, thoroughly amalgamated and partly filled with mercury. They were surrounded by a rim of ebonite and wedged in their places in the cover.

The calorimeter fitted in a light iron frame, from which it was separated by small blocks of ebonite. The whole was surrounded by a tin cylinder fitting closely on the shelf to which the frame was fastened, so there was no draught past the cylinder.

Balances.—Two balances were used, one for weighing the calorimeter, the other in voltameter work. The former could weigh up to thirty pounds and was very sensitive. The latter was an excellent analytical balance. Both were by Trœmner, of Philadelphia, and the weights were compared with standards in his possession.

Thermometers.—The thermometers generally used were by Green, of New York. They were divided into degrees and tenths, and were compared at the Johns Hopkins University with one of the

standards there, the apparatus used in the comparison being that described by Professor Rowland, in his "Determination of the Mechanical Equivalent of Heat." * For the last two calorimeter experiments, a thermometer by Hicks, of London, was used. It was graduated to centimetres and millimetres, and was one of those used by Mr. Leibig, in his work "On the Variation of the Specific Heat of Water." †

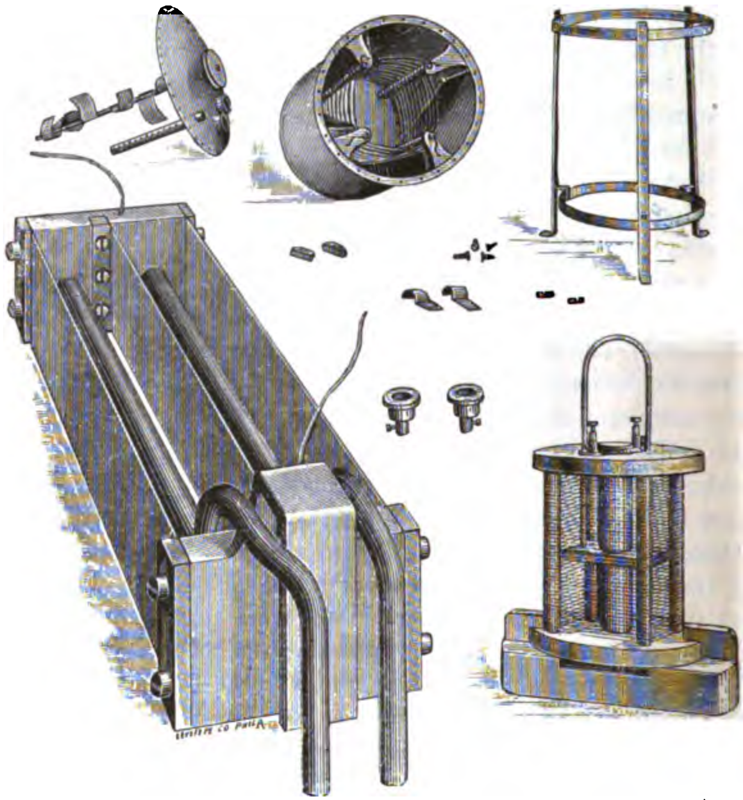


FIG. I. (Calorimeter, Fixed Resistance and Potential Resistance.)

Potential and Current Galvanometers.—These will be described under measurements of potential and current. They, with the other instruments in the test house, rested on stone slabs cemented on the top of heavy wooden posts, sunk about two and one-half feet in the ground.

* Proceedings of the American Academy of Arts and Science, 1880.

† American Journal of Science, July, 1883.

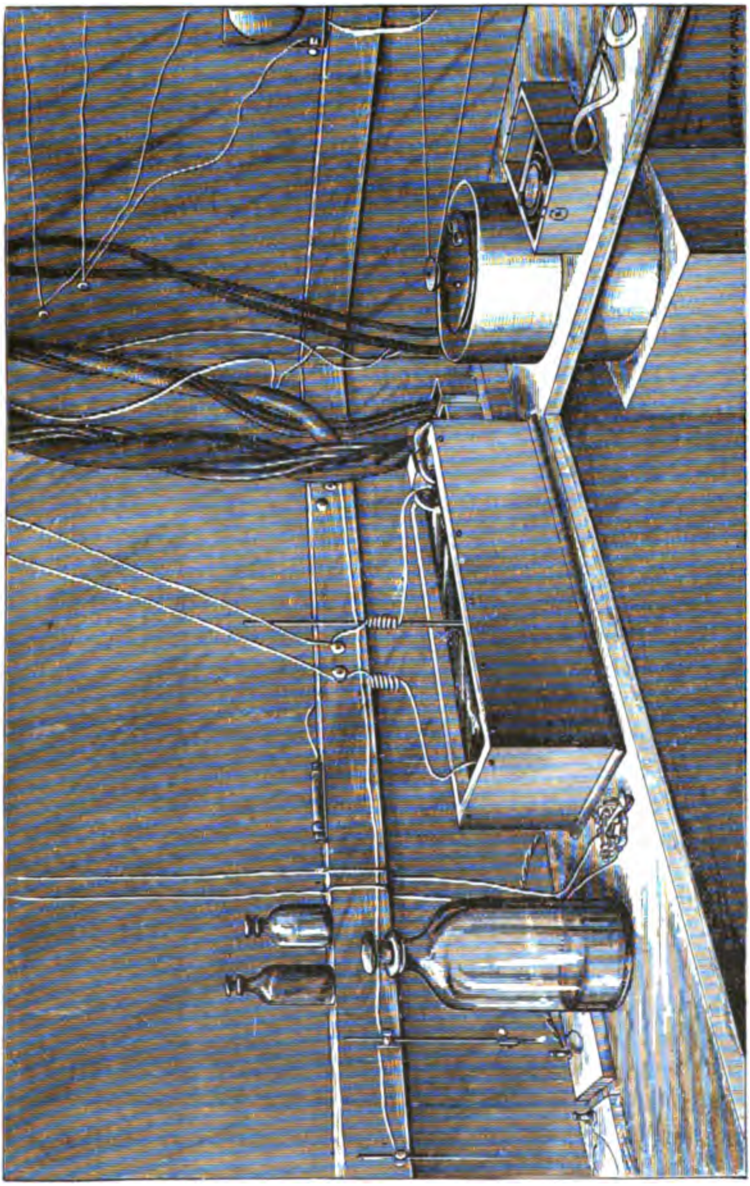


FIG. 2. (Test Room with Instruments in Position.)

METHODS OF MEASUREMENT.

MEASUREMENT OF RESISTANCE.

FOR the standard resistance, a ten B. A. unit coil by Elliott, which had been compared at the Cavendish laboratory, and was used by Professor Rowland in his recent determination of the ohm, was employed. The values of the resistances in terms of this coil were reduced to the Paris ohm, by dividing by

$$1{\cdot}0112.$$

The bridge used in the comparisons was built at the University Workshops, Cambridge, England. Its fixed (equal) arms were connected by a platinum-silver wire bent in a circle, and their ratio changed by making contact with the galvanometer circuit at different points on the wire. Beside the wire was a scale, and on the arm carrying the galvanometer contact, a vernier reading to tenths of a division. When the fixed coils were each one ohm, a whole division of the scale meant a change of one part in 10,000 of the ratio, while with the galvanometer used, a change of one-tenth of a division, or one part in 100,000 could be detected. The bridge had been calibrated for use in the determination of the ohm. With fixed coils of one ohm, the range of the instrument was about ten per cent, so the resistances to be compared were always approximately equal.

The different coils to be compared were balanced against resistances taken from "comparators," designed by Prof. Rowland. Each of these consists of ten coils of equal resistance wound together on a copper cylinder, the whole being coated with wax or paraffine and put inside a larger cylinder, the space between being filled with feathers. At the top, the cylinders are separated by an annular sheet of hard rubber, around which two circles of ten holes each are bored for the terminals. The ends of each coil are taken to copper blocks screwed firmly beneath opposite holes in the two circles. The tops of the copper blocks are thoroughly amalgamated and the holes partly filled with mercury, connections being made by short U-shaped copper rods.

Three comparators of ten, 100 and 1,000 ohms were used, giving a range of from one to 10,000 ohms.

Each coil of the ten-ohm comparator was balanced directly against the ten-ohm standard, then the ten coils in series were

balanced against each of the 100-ohm coils, and finally the 100-ohm comparator in series compared with each of the 1,000-ohm coils. In the measurements, the inner cylinders of the comparators were filled with water and the standard immersed in water, the temperatures being noted.

The zero of the bridge scale was taken as the mean of the readings when the resistances being measured were reversed.

In measuring the resistance boxes, they were kept for six or eight hours in a room whose temperature was nearly constant, and then balanced against corresponding resistances taken from the comparators, the temperatures being, of course, noted.

The coil for potential measurement was immersed in turpentine, its temperature recorded, and its resistance measured as above.

The resistances compared at the Johns Hopkins University were the box for current measurements, the coils and bridge for measuring resistance, and the coil for potential measurement.

MEASUREMENT OF POTENTIAL.

THE GALVANOMETER used for potential measurements was by Hartmann. It was furnished with a Siemens' bell magnet, closely surrounded by a solid copper block, and damped very readily, only making two or three swings before coming to rest. The suspension was a silk fibre about fifteen centimetres long. The coils, specially wound over the regular winding of the instrument, had a resistance of about two ohms.

The galvanometer was in a circuit with resistances that were varied from 1,000 to 150,000 ohms, taken from boxes, two of 100,000, one of 10,000 ohms, the former by Elliott and Breguet, the latter by Bergman. All calibrations being made with the (30,000 + 20,000) Elliott coils in the circuit, it was necessary to compare the other resistances with these coils. The arms of the bridge being made equal, the (30,000 + 20,000) and (40,000 + 10,000) Elliott coils were balanced in succession against the 50,000 Breguet, resistances being added to one or the other until there was no deflection of the galvanometer. It was found that

50,000 Breguet = (30,000 + 20,000 + 280) Elliott.
50,000 Breguet = (40,000 + 10,000 + 250) Elliott.

The (30,000 + 20,000) ohms Elliott was also measured in terms of the bridge coils, and the value found, 49,960, was so nearly

correct that in getting the ratios of the 1,000 and 2,000 ohms Bergman—used in measuring armature resistance—to the (30,000 + 20,000) coils, it was assumed that their values in terms of the bridge coils were the same as if measured in terms of the (30,000 + 20,000) ohms.

The deflections were read by a telescope and scale, the latter by Brown and Sharpe, graduated to centimetres and millimetres. The distance from the telescope to the mirror was two and one-half metres.

Calibrations.—The galvanometer was calibrated, both by measuring a current passing through a standard resistance at whose terminals the leads of the instrument were connected; and by the difference of potential at the terminals of a calorimeter. The constant was also checked with that of the current galvanometer, after each test, by measuring the current through the german-silver strips used for the external circuit of the dynamos, and the potential at their extremities.

During the tests, forty calibrations were made; thirty-six with the silver voltameter and standard coil, and four with the calorimeter. The constants determined by the calorimeter agreed so closely with the measurements by the voltameter, and the labor both of observation and calculation in the former was so much greater than in the latter, that it was thought unnecessary to make the observation any oftener.

Voltameter Calibrations.—The current used varied from one to one and one-half ampères, giving a difference of potential at the terminals of the standard coils of from twenty to thirty volts. The coil shown in *Fig. 1* was of No. 22 german-silver wire, wound on glass rods fixed in a wooden framework. The turns were kept apart by silk cord wound on the rods. The whole was immersed in a high grade oil (300° fire test) kindly furnished by the Standard Oil Company. The oil was constantly stirred while the current was passing. The measurement of the resistance has been described. Its value was

21·161 ohms, at 14° C.

For measuring the currents, a silver voltameter was used, the anode being a spiral of silver wire wrapped in filter paper, the cathode a platinum crucible filled with a 40 per cent. solution of silver nitrate. The calibrations took from ten to twenty minutes, the deposit ranging from ·9 gram to 2· grams. The times were

noted by a chronometer whose rate, + 1 second per day, was neglected.

When the experiment was finished, the solution was poured out of the crucible; the deposit first washed with distilled water, then allowed to soak from one-half hour to twelve hours, then washed again until there was no precipitate with a solution of sodium chloride, and finally slowly dried and then weighed.

A double reading of the galvanometer was taken each minute, and the constant calculated from the mean reading for the time of observation. The constant is given by

$$k_{50} = \frac{C R (1 + M_c (t_c - 14^\circ))}{2d} \left\{ 1 - M_b (t_b - 25^\circ) \right\}$$

where

k_{50} = constant for (30,000 + 20,000) ohms;
R = resistance of standard coil at 14°;
t_c = temperature of standard coil;
M_c = temperature coefficient of standard coil;
M_b = temperature coefficient of box;
t_b = temperature of box;
$2d$ = double deflection of galvanometer;
25° being taken as the standard temperature of the box.

When other resistances were used in the circuit, the constant was multiplied by their ratio to the (30,000 + 20,000) ohms.

Calorimeter Calibrations.—The calorimeter has been described. In making the observations, the time the mercury crossed each half degree or centimetre of the thermometer was taken as the mean of the times of crossing the tenths before and after the division, and the division itself. In calculating the water equivalent of the calorimeter, the weight of the shaft was multiplied by the specific heat of steel; that of the cylinder by the specific heat of copper, and the weight of the glass and wire, by their specific heat. For steel, the value of the specific heat was assumed to be

$$\cdot 1110$$

and that of copper

$$\cdot 0940$$

The principal correction to be applied is due to radiation. The other corrections are for rise of temperature from stirring, for the

part of the thermometer stem in the air, and a small one for weighing in air.

The coefficient of radiation was determined by noting the rate of cooling, the calorimeter being slowly stirred. Experiments gave

Difference between air and calorimeter,	10° C. 1	coefficient, ·00154
" " " " "	5° C.	·00150
" " " " "	0° C.	·00149

Before the experiments, and for the determination of the radiation, the cylinder was carefully polished.

The correction for stirring was determined by bringing the calorimeter to exactly the temperature of the air, and then turning the wheel belted to the pulley on the shaft three times per second. The rise of temperature was ·02° in five minutes. For the smaller velocity used in the later experiments, the heating was assumed to vary as the cube of the velocity.

The correction for the temperature of the stem was taken from

$$c = \cdot000156\, n\, (t - t'')$$

The following is one of the calibrations:

Calorimeter Observations. *Observers*: { Anderson, Duncan, June 20th, 11·40 A. M.

Time of passing ½ Centimetre.	Temperature of Calorimeter.	Temperature of Air.	Absolute Temperature of Calorimeter.	Thermometers.
	CM.			
31–19·8	17·50	27·	24·129	For calorimeter, Hicks No. 108947.
32–35·7	18·	26·9	24·826	For air, Green No.
33–52·3	18·50	26·8	25·523	
35–08·3	19·	26·9	26·221	Water equivalent of calorimeter, corrected for weighing in air
36–23·8	19·50	26·9	26·918	
37–41·3	20·	27·0	27·618	— 8·4311 kilos.
38–56·7	20·50	27·3	28·316	Value of mechanical equivalent used, (corrected for Latitude)
40–14·2	21·	27·4	29·015	
41–29·7	21·50	27·6	29·713	— 425·75
42–46·2	22·	27·7	30·411	

Current: Wyckoff Observer.

Deflection.	Remarks.
17·56	$R = 40$
·56	t_b 23·0
·53	t_s 22·4°
·56	t_t 24·0
·54	
·56	
·54	
·53	
·51	
·48	
·50	
·47	

Potential: Murdock Observer.

Deflection.	Remarks.
10·27	$R = 50{,}000$
·26	$t_b = 22°$
·26	
·26	
·25	
·27	
·26	
·24	
·28	
·26	
·27	
·29	

In making the calculations, Rowland's value of the mechanical equivalent was taken, because the thermometers used in the above experiment were compared directly with those employed by Prof. Rowland, and thus errors in thermometry were to a large extent eliminated. The following are the calculations for the observations:

Interval.	Corresponding Interval in Degrees.	Corresponding Interval of Time		Degrees per Minute.	Same Corrected for Radiation.
centimetres.		min.	sec.		
17·5 to 20·	3·489	6	21·5	·5488	·5473
18 to 20·5	3·490	6	21·0	·5496	·5490
18·5 to 21·	3·492	6	21·9	·5486	·5487
19 to 21·5	3·492	6	21·5	·5492	·5502
19·5 to 22·	3·493	6	22·5	·5479	·5497
				Mean:	·54898

Rise per minute,		·54898
Correction for stirring,	—	·00044
Correction for stem,	+	·00140
Corrected rate,		·54994

$C^2 R$	log, 9·517206
R	log, 9·038541
C^2	log, ·478665
C	log, ·239332
K_0	·02450
K_{50}	·1847 @ 22°

Probably the greatest source of error in the calorimeter experiments was the superheating of the wire in the water. Using platinum-iridium wire varnished, with a smaller current than was generally employed in these experiments, Mr. L. B. Fletcher calculates * that the superheating is about 2° C. But in the measurements described above the wire was bare and the flow of water past it very much faster than in Mr. Fletcher's work. In the last two experiments a rise of 2° C. would cause an error of less than one-tenth per cent., so it is probable that they are not much affected by this source of error.

It is also possible that there was conduction through the water. The calorimeter was carefully cleaned before each experiment and distilled water used. If such an effect existed, it would be in an opposite direction from the superheating.

The usual range of temperature was 10° C.; in the experiment given it was a little over 6°.

Besides the regular calibrations, the constant was calculated after each test, from the potential at the extremities of the german silver "dead resistance," the current being measured by the current galvanometer, and the resistance measured by the bridge. The following partial list of calibrations excludes measurements made in this way. It includes the time during which most of the tests were made—from June 11th to June 23d:

* American Journal of Science, July, 1885.

Date.	Value of K_{60}	Constant Used.	Method.
June.	at 25 degrees.	at 25.	
11	1·845	1·847	Voltameter.
11	1·8465	1·847	Voltameter.
12	1·847	1·847	Voltameter.
12	1·847	1·847	Voltameter.
13	1·844	1·844	Voltameter.
14	1·842	1·844	Voltameter.
16	1·843	1·844	Voltameter.
17	1·843	1·844	Voltameter.
18	1·845	1·844	Voltameter.
19	1·8434	1·843	Calorimeter.
19	1·844	1·843	Voltameter.
20	1·8485	1·843	Calorimeter.
22	1·843	1·843	Voltameter.
23	1·843	1·843	Voltameter.

For the Edison Nos. 5 and 10 dynamos, the potential galvanometer was in the same position as when used for the duration test of lamps, in a room at some distance from the test house. The constant as determined during the tests of these machines agreed closely with that used in the duration tests, which had but just ended. But when the instrument was removed to the test house, the constant began to vary, changing greatly from day to day, with sometimes a sharp change during the day. The Weston No. 7 M dynamo was tested on full load with the constant in this unsatisfactory state, and between the second and third tests there was a change of over one per cent. Although the number of calibrations made these measurements perfectly trustworthy, yet the labor and anxiety were both too great to be repeated with each test.

So before the machine was run on the partial loads, the galvanometer was taken to pieces, the coils rewound and soaked in paraffine, and the stand of the tube carrying the suspension more firmly secured. A beam, which pressed against the wooden pier, was also cut away. After this, the constant did not vary, the calibrations rarely differing more than one-tenth per cent. from the constant used.

MEASUREMENT OF CURRENT.

The currents were measured by observing the ratio of the potentials at the ends of a fixed resistance when a known current and the current to be measured were passing respectively. To do this, the terminals of a circuit containing a galvanometer and a resistance box were permanently fastened to the extremities of the fixed resistance. A current was sent through the latter, and the resistance of the box adjusted until the proper deflection of the galvanometer was obtained; the current was measured by the voltameter, tangent galvanometer, or calorimeter, and the deflection and resistance were observed. When any other current was to be measured, the box was changed until the deflection was about the same as before, and both the deflection and resistance noted. The thermometers used in getting the temperatures of the different parts of the circuit were those by Green, already described.

The notation and formulæ used are as follows:

Let C' be the current used in calibration;
r' be the resistance used in calibration;
d' be the deflection used in calibration;
t'_s be the temperature of fixed resistance at calibration;
t'_b be the temperature of resistance box at calibration;
t'_g be the temperature of galvanometer at calibration;
C'' be the current to be measured;
r'' be the corresponding resistance;
d'' be the corresponding deflection;
t''_s be the corresponding temperature of fixed resistance;
t''_b be the corresponding temperature of the box;
t''_g be the corresponding temperature of galvanometer;
t_0 be the standard temperature $= 25°$ C.;
u_g be the temperature coefficient for galvanometer circuit;
u_s be the temperature coefficient for fixed resistance and box;
G be the galvanometer resistance;
k be the constant at $25°$ C.

Then

$$k = \frac{C'}{2d'} \frac{1 + u_s(t'_s - t_0)}{\left[\, G\{1 + u_g(t'_g - t_0)\} + r'\{1 + u_s(t'_b - t_0)\}\,\right]}$$

$$C'' = k\ 2d'' \Big[1 - u_s (t''_s - t_0)\Big] \Big[G (1 + u_g (t''_g - t_0)) + r'' (1 + u_s (t''_b - t_0))\Big]$$

Calculations were facilitated by making tables of

$$G \{1 + u_g (t_g - t_0)\}$$

for the different temperatures, of

$$r \{1 + u_s (t_b - t_0)\}$$

for the different resistances that were to be used, and of

$$1 - u_s (t_s - t_0)$$

for the different temperatures of the fixed resistance.

Galvanometer.—A mirror galvanometer, by Edelmann, of Munich, was used. It was furnished with a ring magnet damped by surrounding copper blocks. The suspension, originally about two feet long, was shortened to about seven or eight inches by a copper rod passing inside the glass suspension tube; there was no trouble from vibrations. The coils were movable on graduated bars, but for the tests they were clamped and their position never changed. The resistance of the coils, with the fixed resistance and the leads to it, was

·3973 ohms, at 25°.

This was taken as G in the formulæ, and the temperature coefficient for copper used; the value of the german silver fixed resistance being only about ·0004 ohms, and the rest of the circuit being copper. The galvanometer was read with a mirror and scale, the latter being of porcelain, graduated to centimetres and millimetres. The distance from the galvanometer was 2·5 metres.

Resistance Box.—The resistance box, by Hartmann, being open at both ends and having no paraffine on the coils, was very well fitted for its work. Its measurement has been described.

Fixed Resistance.—The details of the fixed resistance are shown in *Figs. 3, 4 and 5*, which are respectively, a plan, side elevation, and end view. It is also shown in perspective in *Figs. 1 and 2*. It consisted of three strips of german silver, 4½ inches broad by ·036 inches thick, the ends hard-soldered into heavy copper blocks.

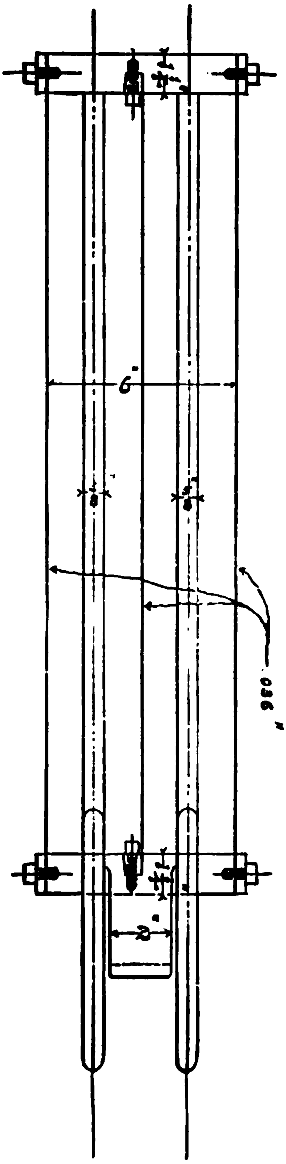


FIG. 3. (Plan.)

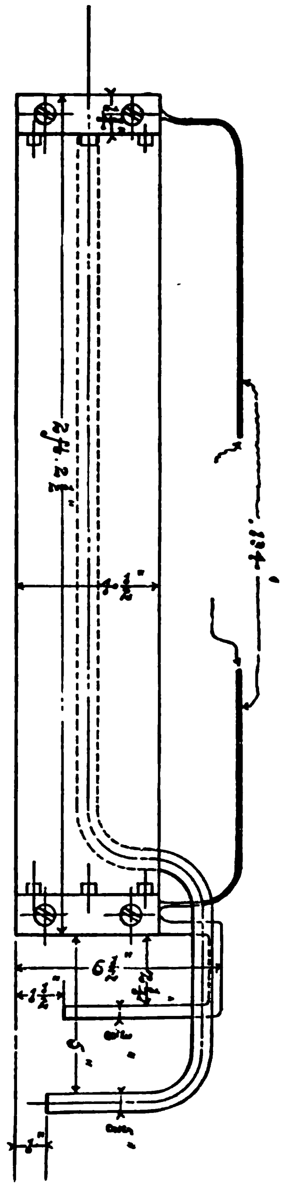


FIG. 4. (Side elevation.)

One of the blocks had a terminal piece cast on it that was bent to clear the edge of the tank in which the resistance was placed, and dipped into a mercury cup, to which one of the main leads was brought. From the other block, two copper rods passing between the strips, were bent over the edge of the tank and dipped with the other main lead into another mercury cup. The terminals of the galvanometer circuit were soldered into the copper blocks and remained permanent during the tests. The whole was put in a rectangular tank filled with the same kind of oil as was used for the potential resistance.

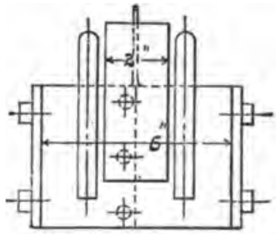


FIG. 5. (End view.)

Calibrations.—Calibrations were made by sending a current through the fixed resistance, measuring it, observing the deflection of the galvanometer and the resistance in its circuit, and noting the temperatures. The calibrations usually lasted ten minutes. The constant was calculated by the formula already given.

Three methods of measuring current were used; the silver voltameter, tangent galvanometer and calorimeter.

For the voltameter calibrations, a large platinum dish was used as cathode, a flattened spiral of silver wire wrapped with filter paper as anode, while a forty to fifty per cent. solution of silver nitrate was employed. With this strength of solution and with the usual current, about four ampères, the deposit was very regular and beautiful. It was treated as described under potential measurements. The resistance in the circuit was about ten ohms.

The tangent galvanometer has been already described. Two observers read both ends of the needle on each side of the zero mark. The current was reversed every minute; it varied from twenty to thirty ampères.

The method of using the calorimeter has been described The observations give $C^2 R$, and R being measured by the bridge, C may be found, with the advantage that errors of observation are halved in the value of C.

Altogether, there were five calibrations by the tangent, nine by the voltameter and five by the calorimeter. The following are the values obtained:

·024510 by voltameter.
·024510 by voltameter.
·024440 by tangent galvanometer.
·024550 by tangent galvanometer.
·024510 by voltameter.
·024480 by voltameter.
·024590 by tangent.
by calorimeter.
·02455 by tangent.
·02455 by voltameter.
·024481 by calorimeter.
·024477 by calorimeter.
·024520 by tangent.
·024500 by voltameter.
·024516 by voltameter
·02453 by calorimeter.
·024495 by voltameter.
·024494 by voltameter.
·02450 by calorimeter.

THIS PRINCIPLE of measuring current has been used before, notably at the Vienna and Munich Exhibitions, but as employed in the following tests the method differs from that previously used in an important particular, *i. e.*, the construction of the fixed resistance. The substitution in the fixed resistance of german silver strips in oil instead of the copper bars in air formerly employed, increased greatly both the range and accuracy of the method.

As the method has not been commonly used, and is possibly not very generally understood, a brief discussion of the sources of error and their probable value in these tests will be given.

The possible sources of error are:

(1.) In observing the deflections;
(2.) In the constant;
(3.) In the temperature correction for fixed resistance;
(4.) In the temperature correction for resistance box;
(5.) In the temperature correction for galvanometer;
(6.) In the values of the coils in the box;
(7.) In the resistance of the galvanometer coils;
(8.) In assuming the currents proportional to $2d$.

(*1.*) Error in observing the deflections.

This error would enter directly in the result. The scale could be read with considerable accuracy to tenths of millimetres; the double deflections were usually between twenty and thirty centimetres. The currents measured were quite steady, but even if they varied, the excellent damping of the galvanometer would allow the readings to be taken with a good deal of precision.

(*2.*) Errors in the constant.

On looking at the table of constants, it will be seen that the results obtained with different resistances in the galvanometer circuit, different currents, temperatures and deflections, and by entirely independent methods of measuring current, agree so closely that their mean must be very near the true constant. Two of them, exceptional ones, differ from the mean by one-third per cent., a few more by one-sixth per cent., but the greater number are within one-tenth per cent. of the constant used. Double weight was given the voltameter calibration, as involving less possibility of error than the other methods; with two exceptions, they are within one-fifteenth per cent. of the mean. Any error would enter directly.

(*3.*) Errors in the temperature correction of the fixed resistance.

The uncertainty due to the temperature correction of the fixed resistance must have been inappreciable. Its temperature coefficient was small, about one-tenth that of copper, while its temperature, considering the large surface of very thin metal exposed to the liquid, must have been quite accurately known. For the heavier currents, the oil was constantly stirred. With about 400 ampères in the circuit, the thermometer registered $\cdot 1^\circ$ C. more when held against the strip than when in the body of the liquid; while the oil rose $1\cdot 5^\circ$ during the test. To further decrease the possibility of error, the oil was kept within at the most 5° or 6° of the usual temperature of calibration by cooling it when necessary between the tests. An error would enter directly in the results.

(*4.*) Errors in the temperature correction of the resistance box.

Both ends of the box were open to the air and the coils were not coated with paraffine. The bulb of the thermometer lay against or very near the coil in use. The currents could cause no appreciable heating and the temperature of the room changed slowly.

The temperature coefficient was taken as

$$\cdot 0004,$$

and calibrations made at different temperatures showed that this was not much in error. Errors would enter almost directly in the result.

(*5*.) Errors in the temperature correction of the galvanometer coils.

The temperature of the galvanometer coils was given by a thermometer hung near them. With the smallest resistance used, any error in this correction would only enter as one twenty-fifth in the result.

(*6*.) Errors in the values of the coils in the resistance box.

The measurement of the resistance box has been described. The values were probably correct within one part in 2,000 or 3,000. Any error would enter directly in the result.

(*7*.) Errors in the resistance of the galvanometer circuit.

The resistance of the galvanometer and its circuit was measured by the standardized bridge. The error was probably small and entered at the most as one twenty-fifth in the result.

(*8*.) Error in assuming the currents proportional to $2d$.

This error is slight and was to a large extent eliminated by making the calibration on about the same part of the scale as the measurements.

The only errors then that would be appreciable are in the deflections, the constant, the temperature correction of the box, and the values of the resistance coils. The last of these could hardly have been over one-twentieth per cent.; the temperature correction of the box was probably within one-tenth per cent.

This method has several advantages. The range is very great (with the apparatus described currents of from two or three ampères to 400 could be measured with about the same accuracy) while the errors are not multiplied in the result and are of such a nature that with proper precautions many of them can be almost entirely eliminated, and the rest made very small.

Although in measurements of both potential and current any change in H would directly affect the results, yet as certainly two

and usually more voltameter calibrations were made for each day of the tests, and the constants were checked after each measurement, it is not probable that any important error arose from this cause.

It is also interesting to note that the magnetometer records that showed such irregularities during the life test of lamps* just finished, were remarkably uniform during the dynamo tests.

POWER MEASUREMENTS.

THE general principle of the Tatham dynamometer is shown in *Fig. 6*. The power applied to the shaft on which the driving pulley *D* is fixed, is transmitted to the pulley *B*, to whose shaft the machine to be tested is coupled, by an endless belt, which passes

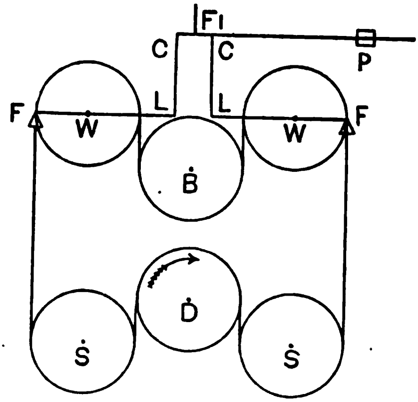


FIG. 6.

over *D*, under the stretching pulley *S*, over the weighing pulley *W*, under *B*, over the second weighing pulley *W*, under *S*, back to the place of starting. Each of the weighing pulleys *W* is supported in a cradle, the outer end of which is pivoted on the knife edge *F*, while the inner end is supported by the link *L C*. The upper ends of the two links are fastened to the scale beam *F*, *P* at equal distances from and on either side of the fulcrum *F*.

To calculate the power applied to the pulley *B*, it is necessary to know three things: The difference of tension of the belt on the two sides of *B*; its effective diameter, and its number of revolutions. These will be discussed in order.

The scale beam is acted upon through the links *L C*, fastened

* JOURNAL FRANKLIN INSTITUTE, Sept., 1885.

to the cradles of the weighing pulleys *W*. The tensions of the belt on the outer faces of these pulleys have no effect on the beam, since the line of effort of the belt passes through the knife edges *F*. The only forces then that act on the beam are the two tensions of the belt on the inner faces of the pulleys *W*, *and these are the tensions on the two sides of B;* and the links being at equal distances on either side of *F*, the *difference of the tensions* is recorded on the beam.

The scale beam was of steel, graduated by Brown and Sharpe into 600 divisions. With the weight used each division meant one-half pound. A small poise travelling on the weight allowed readings to be taken to $\frac{1}{200}$th of a pound.

There were two adjustments to the cradles. In the first, the axis of the pulley *W* was moved by micrometer screws to such a position that the line of effort of the belt passed through the knife edges of the cradle. To show this, the pulley was chocked, a short piece of the belting hung on its outside face, and weights placed in a pan hanging to the belt. When there was no effect on the scale beam, the adjustment was accomplished.

The second adjustment determined the position of the knife edge to which the links were connected. This was moved until the beam weighed about 250 pounds correctly to within one-twentieth of a pound

The pulley *B* was calculated to deliver 6·6 feet per revolution, but the belting used was thicker than was at first intended, and the value 6·6 should be increased by one-fourth per cent. The effective diameter of the pulley, including the thickness of the belt, was measured directly, and also calculated from the length of belt delivered by five turns of the pulley. For the latter measurement, two steel points, one of which was fitted with a micrometer screw, were fixed on a wooden rule, and their distance apart accurately determined on a standard scale. Marks were made on both the pulley and belt opposite to fixed pointers. Five revolutions were given the pulley, and the length of belt that passed the pointer was measured by the rule with the steel points, any margin being taken off by a pair of compasses. The pulley was turned both ways and the effect of stretching eliminated.

The two methods checked very closely, and gave for the delivery of the pulley

6·6 (1·0025) feet per revolution.

A very ingenious mechanical counter registered the number of revolutions. Observations could be taken each minute, and the counter recorded continuously to 1,000,000 revolutions.

Having the difference of tension on the two sides of *B*, its delivery per turn, and number of turns per minute, the horse-power is calculated as follows:

$$\text{Horse-power} = \text{divs. scale beam} \times \text{no. revs.} \times \frac{66\,(1{\cdot}0025)}{2 \times 33000}.$$

$$\text{Horse-power} = 1{\cdot}0025 \left\{ \frac{\text{divs. scale beam} \times \text{no. turns per min.}}{10{,}000} \right\}$$

It will be seen that the only part of the friction of the dynamometer that appears in the readings, is that due to the bearings of the pulley *B*. By the principle of Morin, that the sum of the tensions on the two parts of a belt is constant, this friction should be the same whatever the load. In getting the power applied to a machine, after the measurements have been made with the machine coupled to the dynamometer, it was uncoupled and the dynamometer run at the same number of revolutions, the scale beam observed, and its reading subtracted from the reading when coupled.

To avoid the uncertainty of loss due to belting, the shaft of the driven pulley *B* was coupled directly to the dynamo by a universal coupling, as shown in *Fig. 7*. It was assumed that this would allow for any slight inexactitude in lining the dynamo and dynamometer shafts, but it is doubtful if it was of much value at the high speeds used for the tests.

The figure of the dynamometer (*See Frontispiece*) gives a view of it as used in these tests. The automatic recorder for the scale beam, shown in the figure, was not used. In making observations, the number of revolutions and scale beam were read each minute, usually for ten minutes. The means of the two sets were multiplied together, the product divided by 10,000, and a correction of one-fourth per cent. applied, as given in the formula.

The delicacy and range of the dynamometer were both very great. On one occasion the power absorbed by a single Weston mammoth lamp was accurately measured, while the slightest variation of the load could be at once detected. During a test, the scale beam usually floated steadily, the slight and rapid jar caused

by running served to limber up the weighing apparatus and render it especially sensitive. Indeed, it would be hard to fix a limit to the accuracy with which the observations could be taken.

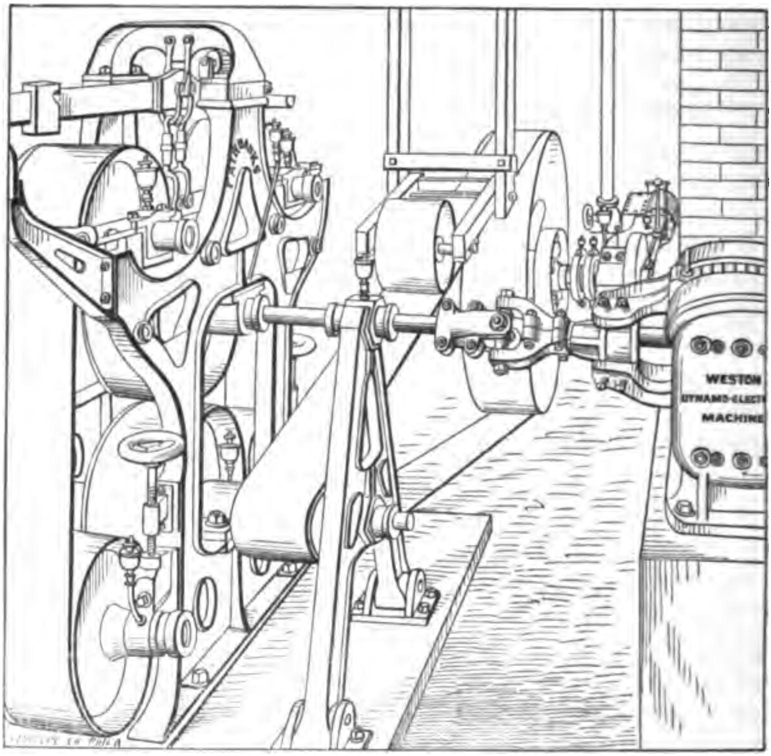


FIG. 7.—Universal Coupling.

Mr. Tatham has published a paper,* giving the principles involved in the dynamometer, and describing its various modifications of form.

The engine used was a 10″ x 20″ Salem Buckeye. Its governor adjustment could be readily varied from 100 to 200 revolutions. The speed, under the steady load of a dynamo, was very uniform.

A steel boiler, loaned by the Baldwin Locomotive Works, was used. It could safely carry 150 pounds per square inch and develop eighty horse-power.

* JOURNAL FRANKLIN INSTITUTE, Dec., 1882. Vol. cxiv.

CHECKING THE DYNAMOMETER.

In order to make the tests absolutely, as well as relatively accurate, it was decided to check the work recorded by the dynamometer against an amount of work calculated from the mechanical equivalent of heat.

To do this, a calorimeter was constructed, the general plan of which is shown in side and end section in *Figs. 8* and *9*.

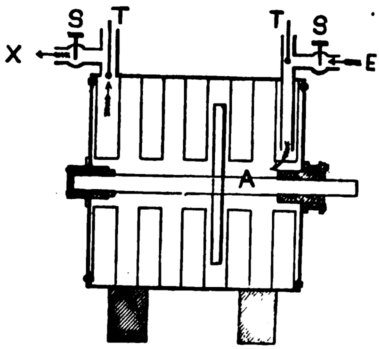


Fig. 8.

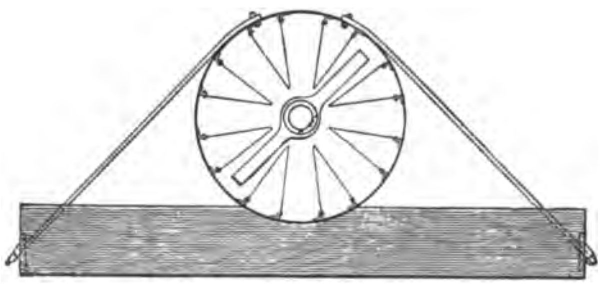


Fig. 9.

It was of wrought iron, 3 feet long by 3 feet in diameter, with V-shaped projections riveted inside the shell. The paddles, 30 inches long by ½ inch thick, were keyed to the shaft and moved between the V's. One end of the shaft passed through the end of the calorimeter, and was coupled to the dynamometer. In the experiments but one paddle was used, 700 revolutions absorbing about forty-five horse-power.

Two different methods of experiment were employed; first, with a constant weight of water and an increasing temperature;

and second, with a constant temperature and a continuous flow of water through the calorimeter.

First Method.—In the first method, the calorimeter was filled and its water equivalent found, the engine was then started, and the rise of temperature noted and the dynamometer observed. The mechanical equivalent was calculated from the work recorded by the dynamometer, the water equivalent of the calorimeter and the rise of temperature, the necessary corrections being applied to the latter. The value thus obtained was compared with the values of Joule and Rowland.

In getting the water equivalent, the calorimeter was first weighed empty and then when filled with water. The difference gave the weight of the water, and the water equivalent of the iron was calculated from its weight and specific heat. It was intended to determine by experiment the specific heat of the specimens of the iron used in the calorimeter, but circumstances made this impossible. The value used,

$$\cdot 112,$$

is taken from determinations by Bystrom, Weinhold, Regnault and Bede, reduced to 30° C. The values given by these different experimenters agree very well, and it seems probable that the mean does not differ from the specific heat of the iron used in the calorimeter by more than one or two per cent. at the most—an error that enters as about one-tenth in the result.

The weighings were made with a scale beam by Fairbanks. Both the weights and graduation had been tested.

The following are the results obtained:

Weight of calorimeter alone,	1228·75 pounds.
Weight of calorimeter with water,	2451·75 pounds.
Weight of water,	1223·0 pounds.
Water equivalent of the iron,	137·62 pounds.
Total water equivalent,	1360·62 pounds.
Correction for weighing in air,	1·38 pounds.
Water equivalent, corrected,	1362·00 pounds.

Temperature Observations.—The thermometers used were those by Green, already described. The time the mercury crossed each half degree was observed and was taken as the mean of the times of crossing the tenths below and above the division, and the division itself. The times were noted by a chronometer.

The following table gives the temperature observations and the dynamometer readings,—the latter were taken each minute:

Calorimeter Observations for Checking Dynamometer, June 27.

Temperature.	Observed Time of Crossing Division.	Corrected Time of Crossing Division.	Intervals for 4·5° C.	Remarks.
30·5	12–01–44·	12–01–44·		The times were corrected arbitrarily by the observations on either side.
31·	02–20·3	02–20·3		
31·5	02–57·0	02–56·8		
32·	03–33·3	03–33·3		
32·5	04–09·6	04–09·7		
33·	04–46·0	04–46·3		
33·5	05–22·3	05–23·1		
34·	06– 1·6*	06–00·2		
34·5	06–37·6	06–37·3		
35·	07–14·0	07–14·4	5–30·4	
35·5	07–51·6	07–51·6	5–31·3	
36·	08–29·0	08–29·0	5–32·2	
36·5	09–07·3	09–06·2	5–32·9	
37·	09–43·3	09–43·4	5–33·7	
37·5	10–20·3	10–20·6	5–34·3	
38·	10–58·0	10–58·0	5–34·9	
38·5	11–36·0	11–35·5	5–35·3	
39·	12–13·0	12–13·0	5–35·7	

*Untrustworthy, only one reading.

Dynamometer Readings.

Time.	Counter.	Scale Beam.	Friction.	Remarks.
12–01–00	0159			
02–00	0881	665	13·72	
03–00	1603	666	13·72	
04–00	2326	664	13·72	
05–00	3042	661	13·72	
06–00	3761	661	13·72	
07–00	4479	661	13·72	
08–00	5198	663	13·72	
09–00	5916	666	13·72	
10–00	6640	666	13·72	
11–00	7360	666	13·72	
Mean:	720·1	663·9	13·72	

The corrections to be applied to the thermometer readings are for the part of the stem in the air, and for radiation. The first of these is somewhat indefinite, as a portion of the stem is heated

by conduction from the calorimeter. The whole correction, however, is only about one-third per cent., and its value is probably correct within twenty or thirty per cent. so the error in the result from this cause can hardly be much over one-tenth per cent.

But the most important correction, and the one in which there seems the greatest possibility of error, is the coefficient of radiation. This is usually determined by slowly stirring the calorimeter, and noting its difference of temperature from the air and rate of cooling, correcting for the heat developed in stirring. But with a single thin blade, and no arrangement for causing circulation, this method was impracticable. In some experiments that were tried, the water was not thoroughly mixed, and the cool water falling and warm water coming to the top, made the values obtained worthless.

Under these circumstances, it became necessary to calculate the radiation from the experiment for the determination of the mechanical equivalent.

The method of calculation was as follows: The observations were divided into intervals of 4·5° C., as shown in the following table, and the corresponding intervals of time were reduced to the same rate of doing work, the same value of the specific heat of water, and the same value for the stem correction of the thermometer. The remaining difference in the intervals is assumed to be due to radiation.

Calculation of Radiation.

INTERVAL.	Time Interval Uncorrected.	Ratio of Rate of Doing Work to Mean Rate.	Correction for Specific Heat of Water.*	Correction for Stem in Air.*	Time Interval Corrected.	Excess over First Interval.
degrees.	minutes.	×	÷	÷	minutes.	minutes.
30·5—35·	5·5067	1·00145	1·00000	1·00000	5·51467	·00000
31· —35·5	5·5217	1·00026	1·00000	1·00016	5·52224	·00757
31·5—36·	5·5367	·99957	1·00010	1·00032	5·53200	·01733
32· —36·5	5·5483	·99885	1·00020	1·00048	5·54196	·02729
32·5—37·	5·5617	·99847	1·00031	1·00065	5·54808	·03341
33· —37·5	5·5717	·99824	1·00040	1·00081	5·55530	·04063
33·5—38·0	5·5817	·99980	1·00050	1·00097	5·57250	·05783
34· —38·5	5·5883	1·00134	1·00060	1·00113	5·58607	·07140
34·5—39·	5·5950	1·00219	1·00070	1·00130	5·59600	·08133

Gives radiation ·00258° per degree per minute.

* These are the ratios of each succeeding interval to the first interval.

The differences of these corrected intervals from the first interval were plotted, the excess of the mean temperatures of the intervals over that of the air being taken as abscissæ, and the above differences as ordinates. A straight line was drawn through the points thus found. The radiation was calculated by taking the difference of the ordinates for an interval of 4°, and from this value (which is the loss of time due to radiation, in an interval of about 5·55 minutes, the difference of temperature being 4°), the coefficient of radiation was easily found.

In drawing a straight line through the points, we have assumed the coefficient of radiation to be constant when the excess of temperature over that of the air varies, instead of increasing with the excess. Within the rather narrow limits of temperature used, however, the value found represents very nearly the radiation for the mean interval. In calculating the experiment by the second method, the value of the radiation found above was corrected to the greater difference of temperature between the calorimeter and air, by increasing it in the ratio shown by the experiments of McFarlane and Rowland

This method of calculating the radiation; while not so accurate as the method usually employed, has the advantage that the conditions of observation are accurately those of the experiment to which the radiation is applied.

It will be seen that the errors likely to affect the radiation coefficient, are errors of observation, in the relative values of the specific heat of water at the different temperatures, and in the ratios of the stem corrections.

As for errors of observation, the dynamometer readings for the intervals were the mean of five observations, and, although the jar interfered somewhat with the readings of the thermometer, yet the table shows that there were no very great errors, and the method of observation allowed the readings to be to some extent corrected by those on either side.

The ratios of the values of the specific heat of water for the different intervals were calculated from Rowland's values of the mechanical equivalent for the mean temperatures of the intervals. Fortunately the correction was small, and probably accurately given.

Whatever the absolute value of the stem correction might have

been, there could be little error in the relative values for the different intervals.

The result obtained was:

Excess of cal. over air, 4° C.	coefficient of radiation, ·00258
8° C.	·00262

On applying the above values to the observation by the first method, we obtain:

Mean rise of temperature, per minute (uncorrected)	·809814
Mean correction for radiation,	+ ·017790
Mean correction for stem,	+ ·003034
Mean correction to absolute temperature,	— ·001350
Mean rise, per minute (corrected)	·822288
Water equivalent of calorimeter,	1362·0 pounds.
Heat units developed, per minute,	1119·9562
Mean reading scale beam,	663·9
Friction reading scale beam,	13·72
Difference reading scale beam,	650·18
Mean revolutions,	720·1
Work in foot pounds = product × 3·3 × 1·0025	15489048
Mechanical equivalent for 1° C,	1383·01 ft. lbs.
Mechanical equivalent for 1° F.,	768·34 ft. lbs.

Unfortunately, however, the construction of the calorimeter made the results of this experiment untrustworthy. The blades were kept apart by pieces of 4-inch pipe, ⅛ inch thick, fitting over the shaft between them. In the space between the shaft and pipe were about five pounds of water not in circulation with the mass in the calorimeter. The shaft being jacketted with this layer of water, must have gained heat but slowly. The result was that the heat units calculated were too great, and the mechanical equivalent too small. It is also probable that this effect would make the coefficient of radiation calculated from this experiment slightly too large.

We can only say of this experiment then that the value is

768·3 + an indeterminate correction.

Second Method.—In this method water was made to flow continuously through the calorimeter. The engine was run until the temperature of the exit water ceased to rise, and then observations of the entrance and exit temperatures and of the dynamometer were taken each minute, and the exit water weighed every four minutes. The weighings were made by two of Fairbanks' platform scales that had been tested with standard weights. The observations lasted one and one-half hours. The heat units were calculated for each interval of four minutes, as shown in the table, and their sum taken for the whole interval. The scale reading and number of revolutions of the dynamometer were averaged for the time of the experiment, the work being calculated from the means (Philadelphia time).

Continuous Calibration.—Tatham Dynamometer, June 27, 1885.

Time.	Mean Temperature Exit.	Mean Temperature Entrance	Increase.	Weight H_2O	Heat Units.
11·02					
·06	39·528	23·82	15·708	287·25	4512·123
·10	39·5975	23·8225	15·775	267·00	4211·925
·14	39·65	23·8125	15·8375	261·25	4137·546875
·18·30	39·7125	23·815	15·8975	293·75	4669·890625
·22	39·7025	23·82	15·8825	235·00	3732·3875
·26·30	39·67	23·8025	15·8675	310·50	4926·85875
·30	39·645	23·80	15·845	228·75	3624·54375
·34	39·6125	23·80	15·8125	271·25	4289·140625
·38	39·6150	23·805	15·810	274·00	4331·94
·42	39·5875	23·8025	15·785	270·75	4273·78875
·46	39·5875	23·8275	15·76	274·00	4318·24
·50	39·5375	23·845	15·6925	276·00	4331·13
·54	39·52	23·8525	15·6675	275·00	4308·5625
·58	39·485	23·84	15·645	276·00	4318·02
12·02	39·4450	23·84	15·605	277·75	4334·28875
·06	39·3425	23·85	15·4925	289·00	4477·3325
·10	39·255	23·86	15·395	286·25	4406·81875
·14	39·1425	23·8825	15·26	287·00	4379·62
·18	39·0775	23·8925	15·185	284·75	4323·92875
·22	39·0125	23·90	15·1125	284·00	4291·95
·26	38·98	23·91	15·07	289·25	4358·9975
·30	38·895	23·91	14·985	287·50	4308·1875
·34	38·865	23·91	14·955	290·50	4344·4275
·38	38·78	23·905	14·875	293·50	4365·8125
·42	38·8175	23·915	14·9025	275·50	4105·63875
·46	38·93	23·925	15·005	272·25	4085·11125
·50	39·04	23·925	15·115	270·50	4088·6075
·54	39·175	23·94	15·235	265·50	4044·8925
·58	39·3475	23·925	15·4225	263·50	4063·82875
1·02	39·405	23·9125	15·4925	271·00	4198·4675
·06	39·45	23·9025	15·5475	273·25	4248·354375
1·10	39·4825	23·90	15·5825	272·50	4246·23125
·14	39·485	23·92	15·565	273·00	4249·245
·18	39·4925	23·92	15·5725	268·00	4173·43
·22	39·525	23·905	15·62	267·50	4178·35
·26	39·51	23·90	15·61	274·75	4288·8475
·30	39·52	23·895	15·625	268·00	4187·5
Total number heat units.					157735·96550

When the experiment was finished, the two cocks on the calorimeter were closed, and the engine stopped. The temperature of the water was then found to be 39°. The time occupied in stopping was about four minutes, equivalent to two minutes on full load. From the data of the previous experiment, the rise of temperature would be about ·85° C. per minute, and therefore the average temperature of the calorimeter during the second experiment was about 37·3°.

From the above table and the dynamometer record, we get the following data:

Mean reading scale beam,		655·9195
Mean friction reading,		13·72
Corrected reading,		642·1995
No. revolutions,		106,180
Foot pounds absorbed,		225585395·
Heat units passing through cal. (uncorrected,)		157735·96
Heat units radiated from calorimeter,	+	4045·89
Correction to reduce ther. to abs. temp.,	—	169·63
Stem correction,	+	647·12
Total heat units,		162169·34
Mechanical equivalent for 1° C.,		1391 05 foot pounds.
Mechanical equivalent for 1° F.,		772·81 foot pounds.

In this method the uncertainty due to the specific heat of the iron, and its temperature is avoided. The greatest possibilities of error are in the mean temperature of the calorimeter and the stem correction. It is probable that too great a value of the latter has been taken; for the thermometers were in the water for several hours and a considerable portion of the stem must have been heated by conduction.

The coefficient of radiation was taken from the first experiment.

The results of the experiments are:

First method mech. equiv. = 768·3 + an indeterminate correction
Second method mech. equiv. = 772·81

It would seem then that within the limit of error of these experiments, the dynamometer is correct, and, considering the probable accuracy of the last method, there seems little doubt that the work calculated from the dynamometer readings is as accurate as the adjustments of the machine and the readings themselves.

TESTS.

For the full load tests, the machines were run at least ten hours before any measurements were made. They were then tested at intervals of from one to two hours.

For the partial loads, the dynamos were run on quarter load for two or three hours, then tested, then run on half load for a couple of hours, and tested, etc.

The method of making a test was as follows: A time to begin was set, and the observers got ready to start at the signal from the test house. After the signal, double readings of the potential and current galvanometers were simultaneously made each minute, and the scale beam and number of revolutions of the dynamometer observed. The field galvanometer was reversed, and read as often as possible, usually four or five double readings.

At the end of ten minutes, a signal to stop was made; the dynamo was stopped, the field circuit broken, the storage battery put on, and the armature resistance measured. The brushes were then lifted, and the field circuit made and its resistance measured. Finally, the constants of the current and potential galvanometers were checked on the german silver strips.

When the tests for the day were finished, the friction of the armature and of the dynamometer were obtained, and the latter subtracted from the power applied for each test.

Communication from the test house to the dynamo shed was by an electric bell, and through a speaking tube.

The following notation will be used in the formulae:

e	difference of potential between terminals of dynamo;
E	total electro-motive force generated in armature;
i	current in external circuit;
i_s	current in field;
R	resistance of external circuit;
r_a	resistance of armature coils;
r_s	resistance of field with box for adjustment;
S	resistance of field alone;
W	energy applied in horse-power;
W_t	total electrical energy in horse-power;
W_e	energy in external circuit in horse-power;
W_a	energy in armature in horse-power;

W_s energy in field in horse-power;
Ef_t total efficiency of electrical conversion;
Ef_c useful commercial efficiency;
η $= Ef_c / Ef_t$;
p_a percentage of power used in armature;
p_s percentage of power used in field;
n number of revolutions per minute;
Fric. friction of armature;
t_a temperature of the air in degrees centigrade;
t_p temperature of pole-piece in degrees centigrade;

Of these, e, i, i_s, r_a, S, W, n, t_a and t_p were observed directly.

E was calculated from $E = e + (i + i_s) r_a$;

R was obtained from $R = e / i$;

r_s was from $r_s = e / i_s$; it was also checked by observation after each test.

The other formulæ used were

$$W_t = \frac{(i + i_s) e + (i + i_s)^2 r_a}{745 \cdot 3}$$

$$W_e = \frac{i e}{745 \cdot 3}$$

$$W_a = \frac{(i + i_s)^2 r_a}{745 \cdot 3}$$

$$W_s = \frac{i_s e}{745 \cdot 3}$$

$$Ef_t = \frac{W_t}{W}$$

$$Ef_c = \frac{W_e}{W}$$

$$\eta = \frac{Ef_c}{Ef_t}$$

$$p_a = \frac{W_a}{W}$$

$$p_s = \frac{W_s}{W}$$

EDISON NO. 5 DYNAMO.

Diameter of armature,	$7\frac{1}{16}''$ inner; $7\frac{7}{8}''$ outer.
Weight of machine,	2475 pounds.
Number cf commutator bars,	50
Turns of wire in a coil.	2
Length of useful wire in a coil,	52″
Brushes adjusted or not?	yes.
Diameter of bearing,	$1\frac{5}{16}''$
Length of bearing,	$5\frac{5}{8}''$
Revolutions per minute,	1400
Volts for best work,	125
Ampères for best work,	100

Table 1 gives the result of the measurements:

TABLE I.—(*Edison No. 5 Dynamo.*)

DATE.	May 29th.		
Time,	12·40	1·40	3·00
Load,	Full.	Full.	Insulation of armature gave way.
E. M. F. at terminals, .	125·2	121·59	
Total E. M. F., ...	131·5	128·00	
Current in ext. circ , . .	100·92	98·06	
Current in field, ...	2·385	2·296	
External resistance, . .	1·241$_d$	1·240$_d$	
Armature resistance, . .	·0613	·0638	
Field, with box, ...	52·59	53·08	
Field, alone, ...	. . .	. . .	
Power applied, ...	18·89	18·05	
Total elect. energy, . .	18·23	17·24	
Ext. elect energy, . . .	16·95	16·00	
Energy in arm., ...	·878	·863	
Energy in field, ...	·401	·374	
Total efficiency, ...	96·53	95·49	
Commercial efficiency, .	89·76	88·63	
Economic coefficient, . .	92·99	92·82	
% power in arm., . . .	4·65	4·78	
% power in field, . . .	2·12	2·08	
No revolutions, ...	1400·8	1389·7	
Friction of arm., ...	. . .	. . .	
Temp. of air, ...	26·4° C.	27·° C.	
Temp. of pole-piece, . .	44·° C.	45·4° C.	

This was the first machine tested and the measurements were intended as much to show any weak points in the method as to serve as a test of the dynamo. If no trouble occurred, the work was to be accepted, otherwise it would have been repeated after the causes of error had been removed.

On looking at the table, it will be seen that the efficiencies for the two tests differ by about one per cent. The agreement of the measurements of the current and potentials as shown in the values of the resistances, calculated from them, is very good. Whether the difference is due to the power measurements, or to different conditions of lubrication, velocity, etc., is impossible to say.

After the second test, the insulation of the armature gave way; making it impossible to repeat the full load measurements, or to test on the partial loads.

EDISON NO. 10 DYNAMO.

Diameter of armature,	$9\frac{1}{16}''$ inside; $10\frac{5}{8}''$ outside.
Weight of machine,	4710 pounds.
Number of commutator bars,	64
Turns of wire in a coil,	1
Length of useful wire in a coil,	33″
Must brushes be adjusted?	yes.
Diameter of bearing,	$2\frac{3}{8}''$
Length of bearing,	$9\frac{5}{8}''$
Number turns per minute,	1200
Volts for best work,	125
Ampères for best work,	200

Table II gives the results of the measurements:

There is little to say of the full load measurements of this machine. The extreme difference is about one-half per cent.; the greatest difference from the mean one-fourth per cent.

The dynamo was measured twice on the partial loads. The first set was on the same day as the full load tests, the machine being run on open circuit for a couple of hours after the last full load measurement, then tested for quarter load, then run on half load for a while and tested, etc. The second set, made some days later, showed that the machine had not been sufficiently cooled for the first set of measurements. The total efficiencies, calculated from the two sets of measurements, differ for the quarter load about one and one-half per cent.; for the half load, three-quarter per cent., and for the three-quarter load, one-seventh per cent.

In comparing these total efficiencies, if the difference of armature friction (·152 horse-power) be applied to the first set, we get

	¼ load.	½ load.	¾ load.
First set,	83·10	90·51	92·83
Second set,	83·32	90·55	92·44

But as the measurement of friction was made after the three-quarter load in each case, the values for this load should agree better than for the others. Part of the difference of ·39 per cent. is undoubtedly due to the fact that in the last set of measurements the unsteadiness of the potential galvanometer while measuring the armature resistance, due to changes in the contact resistance of the brushes, was so great that the brushes were held against the commutator, thus giving too small a value of r_a, and therefore of Ef_t. On the whole, the agreement of the two sets is very satisfactory.

Table II.—(*Edison No. 10 Dynamo.*)

Date.	June 1st.				June 1st.			June 4th		
Time,	12·33	2·00	3·15	4·15	6·56	7·45	8·30	11·15	2·35	4·00
Load,	Full.	Full.	Full.	Full.	¼	½	¾	¼	½	¾
E.M.F at terminals,	125·08	122·67	121·58	122·87	125·41	126·09	122·89	127·81.	128·83	125·6
Total E.M.F., . . .	129·35	127·18	126·05	127·27	126·81	128·74	126·85	128·73	130·67	128·33
Current in ext. circ.,	201 48	196·51	194·56	196·48	52·07	107·05	150·60	51·81	103·79	149·92
Current in field, . .	4·021	3·900	3·84	3·93	3·46	3·69	3·74	3·47	3·81	3·81
External resistance,*	·6208$_e$	·6243$_e$	·6249$_e$	·6254$_e$	2 408$_d$	1·177$_d$	·8160$_d$	2·467$_d$	1·213$_d$	·8378
Armature resistance,	·0208	·0225	·0231	·0220	·0253	·0239	·0256	·0167	·0171	·0178
Field, with box, . .	31·10	31·46	31·63	31·27	36·24	34·14	32·83	36·82	33·83	33·01
Field, alone, . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Power applied, . .	37·69	35·98	35 53	36·19	11·556	21·30	28·46	11·459	20·83	28·64
Total elec. energy, .	35 67	34·20	33·58	34·22	9·449	19·13	26·27	9·548	18·86	26·47
Ext. elec. energy, .	33·81	32·34	31·74	32·66	8·762	18·11	24·83	8·884	17·94	25·27
Energy in arm., .	1·178	1·212	1·218	1·182	·105	·393	·820	·0686	·265	·564
Energy in field, . .	·675	·642	·627	·648	·582	·625	·617	·595	·658	·641
Total efficiency, . .	94 61	95 04	94·52	94·56	81·77	89·80	92·30	83·32	90·55	92·44
Commerc'l efficiency.	89 70	89·89	89·34	89·52	75·82	85·02	87·25	77·53	86·12	88·23
Economic coefficient,	94·80	94·58	94·51	94·65	92·73	94·68	94·53	93·05	95·10	95·45
% power in arm., .	3·12	3·36	3·43	3·26	·906	1·85	2·88	·598	1·28	1·97
% power in field, .	1·80	1·79	1·76	1·78	5·04	2·93	2·16	5·20	3·16	2·24
No. revolutions, . .	1208 6	1197·6	1193·3	1199·3	1207·6	1207·7	1202·6	1211·7	1211·1	1209·3
Friction of arm., . .	·437	·437	·437	·437	·437	·437	·437	·285	·285	·285
Temp. of air, . . .	30·5° C.	30·5° C.	30.5° C.	28·0 C.	26·5° C.	27·5° C.	27·0° C.	25·5° C.	28 5° C.	31·0° C.
Temp. of polep-iece,	50·5° C.	50·5° C.	51·5° C.	56·5° C.	35·5° C.	44·5° C.	44·0° C.	38·0° C.	45·6° C.	46·7° C.

* The suffix e refers to lamps and d to "dead" resistance.

WESTON NO. 7 M. DYNAMO.

Diameter of armature,	9⅜″
Weight of machine,	3300
Number of commutator bars,	64
Total number of turns in coils,	128
Turns per commutator segment,	2
Average length of a turn,	6 feet, 8″
Must brushes be adjusted?	slightly.
Diameter of bearing, pulley end,	2″
Diameter of bearing, commutator end,	1½″
Length of bearing, pulley end,	7½″
Length of bearing, commutator end,	6½″
Number of turns per minute,	1050
Volts for best work,	160
Ampères for best work,	125

Table III gives the results of the measurements:

As stated under "potential measurements," there was a sharp change in the value of the constant of the potential galvanometer between the second and third tests. The following are the calibrations made:

TIME.	Value of K_{60}.	METHOD.
A. M.	at 25 degrees.	
10·00	1·305	Voltameter with standard resistance.
11·35	1·307	Current galvanometer with german-silver strips.
P. M		
12·50	1·308	Current galvanometer with german-silver strips.
2·50	1·287	Current galvanometer with german-silver strips.
3·05	1·286	Voltameter with standard resistance.
4·15	1 286	Voltameter with standard resistance.

For the first two tests, the value 1·306 was used; for the last two, 1·286.

The tables show a gradual decrease in the efficiencies, the difference between the first and last values being about one per cent

The cause seems to be the different amounts of lead given the brushes. If we compare the first with the third test, it will be seen that, with about the same current in the field and a greater

TABLE III.—(*Weston No. 7 M. Dynamo.*)

DATE	June 8th.					June 12th.			
Time,	11.15	12.26	2.27	3.45	12.00	2.00	3.45	4.30	6.00
Load,	Full.	Full.	Full.	Full.	¼	½	¾	Full.*	½
E. M. F. at terminals,	156.07	154.84	151.42	151.22	163.66	163.41	163.93	166.48	167.60
Total E. M. F.,	165.58	163.99	160.79	160.31	166.07	168.29	172.65	176.30	172.77
Current in. ext. circ.,	125.78	124.86	123.13	123.57	33.26	66.27	99.25	133.82	67.68
Current in field,	2.378	2.340	2.341	2.332	1.738	1.872	2.163	2.439	1.959
External resistance,	1.241$_d$	1.240$_d$	1.230$_e$	1.224$_e$	4.921$_d$	2.466$_d$	1.652$_d$	1.244$_d$	2.476$_d$
Armature resistance,	.0742	.0720	.0747	.0722	.0689	.0716	.0683	.0720	.0742
Field, with box,	65.62	66.18	64.70	64.86	94.16	87.31	75.78	68.25	85.54
Field, alone,	...	...	...	...	...	...	...	...	...
Power applied,	29.29	29.01	28.07	28.17	8.658	16.223	24.123	33.257	17.08
Total elec. energy,	28.47	27.98	27.07	27.08	7.798	15.387	23.25	32.23	16.144
Ext. elec. energy,	26.34	25.94	25.02	25.07	7.304	14.53	21.83	29.89	15.22
Energy in arm.,	1.635	1.562	1.578	1.536	.1131	.446	.943	1.796	.483
Energy in field,	.498	.486	.476	.473	.382	.410	.476	.545	.441
Total efficiency,	97.21	96.48	96.45	96.12	90.08	94.84	96.38	96.92	94.52
Commercial efficiency,	89.92	89.42	89.14	89.00	84.37	89.57	90.49	89.87	89.12
Economic coefficient,	92.51	92.68	92.41	92.58	93.65	94.41	93.90	92.73	94.28
% power in arm.,	5.59	5.39	5.63	5.45	1.31	2.75	3.91	5.40	2.82
% power in field,	1.70	1.68	1.69	1.68	4.41	2.53	1.98	1.63	2.58
No. revolutions,	1043.5	1039.0	1045.6	1051.7	1041.4	1038.8	1024.1	1058.8	1051.3
Friction of arm.,	.3115	.3115	.3115	.3115	.1956	.1956	.1956	.1956	.1956
Temp. of air,	30.° C.	30.5° C.	30.° C.	30.° C.	29.5° C.	31.° C.	30.5° C.	29.° C.	28.° C.
Temp. of pole-piece,	42.° C.	42.2° C.	42.8° C.	47.8° C.	33.3° C.	35.° C.	36.5° C.	36.° C.	35.5° C.

* Unofficial.

number of revolutions of the armature, the *E. M. F.* of the latter test is about five volts less than that of the former. In the last test, with the speed still further increased and with the field current about constant, the *E. M. F.* is slightly less than in the third measurement.

The partial load tests were made after the constant had become steady. After the three-quarter load test, a measurement was made on full load. As it was not made under the provisions of the code, it is marked "unofficial" in the table. The half load test was repeated to check the former measurement. The difference of ·3 per cent in the total efficiencies is probably accounted for by the slight increase of armature friction caused by running on the three-quarter load. The greatest value of the commercial efficiency is on three-quarter load, the slightly less value of the total efficiency, as compared with the full load, being more than counter-balanced by the smaller loss in the armature and field.

WESTON NO. 6 M. DYNAMO.

Diameter of armature,	$8\frac{1}{32}''$
Weight of machine,	2000
Number of commutator bars,	72
Total number of turns,	144
Turns per commutator segment,	2
Average length of a turn,	6 feet 5″
Must brushes be adjusted?	slightly.
Diameter of bearing, pulley end,	$1\frac{5}{8}''$
Diameter of bearing, commutator end,	$1\frac{3}{8}''$
Length of bearing, pulley end,	$6\frac{3}{4}''$
Length of bearing, commutator end,	5″
Number of turns per minute,	1150
Volts for best work,	120
Ampères for best work,	80

Table IV gives the results of the measurements:

The full load measurements probably agree as closely as the conditions of the tests. There was a good deal of sparking at the brushes, and the machine seemed overloaded.

For the partial loads, the total efficiency increased up to the three-quarter load, and there was little sparking at the commutator. On the unofficial full load test, the sparking was quite violent, and the efficiency fell about two per cent. from the three-quarter load. Com-

Table IV.—(*Weston No. 6 M. Dynamo.*)

Date.	June 13th.				June 14th.			
Time,	11·52	1·50	2·25	3·55	12·15	2·20	4·00	4·39
Load,	Full.	Full.	Full.	Full.	¼	½	¾	Full.*
E.M.F. at terminals,	117·4	115·4	118·89	119·86	119·70	122·41	119·19	124·41
Total E. M. F., .	124·59	122·37	126·26	127·17	121·70	126·28	125·12	131·76
Current in ext. circ.	71·85	70·62	72·45	71·56	20·535	39·878	60·705	75·65
Current in field, .	1·277	1·254	1·280	1·286	1·236	1·214	1·246	1·318
External resistance,	$1\cdot634_{d}$	$1\cdot634_{d}$	$1\cdot641_{d}$	$1\cdot675_{e}$	$5\cdot827_{e}$	$3\cdot070_{e}$	$1\cdot963_{d}$	$1\cdot645_{d}$
Armature resistance	·0983	·0969	·0999	·1003	·0921	·0940	·0957	·0956
Field with box, .	91·93	92·00	92·91	93·20	96·79	100·9	95·69	94·42
Field alone, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Power applied, . .	12·89	12·48	13·15	13·17	3·979	7·341	10·774	14·390
Total elec. energy,	12·23	11·80	12·49	12·429	3·554	6·962	10·40	13·606
Ext. elect. energy,	11·32	10·93	11·56	11·508	3·297	6·55	9·708	12·627
Energy in arm., .	·705	·672	·729	·714	.0585	·213	·493	·759
Energy in field, .	·201	·194	·204	·207	·1985	·1993	·1992	·2199
Total efficiency, .	94·82	94·53	94·98	94·37	89·33	94·84	96·53	94·55
Commer'l efficiency	87·79	87·59	87·88	87·38	82·87	89·23	90·10	87·75
Econo'ic coefficient,	92·58	92·66	92·53	92·59	92·77	94·08	93·34	92·80
% power in arm., .	5·48	5·38	5·56	5·43	1·47	2·90	4·58	5·28
% power in field, .	1·56	1·56	1·56	1·57	4·99	2·71	1·85	1·53
No. revolutions, .	1099·6	1101·9	1117·8	1114·9	1110·7	1109·5	1113·7	1154·2
Friction of arm., .	·298	·298	·298	·298	·1672	·1672	·1672	.1672
Temp. of air, . .	30·4° C.	31·° C.	30·5° C.	30·5° C.	34·° C.	33·5° C.	. . .	. . .
Temp. of pole-piece	37·7° C.	41·2° C.	41·6° C.	41·5° C.	36·7 C.	39·5° C.	. . .	. . .

* Unofficial.

paring the unofficial full load with the tests of the day before, and applying the difference of armature friction to the former, it will be seen that the total efficiency for the unofficial test is less, the load being greater and the efficiency at this load decreasing rapidly as the load increases.

EDISON NO. 4 DYNAMO.

Diameter of armature, $6\frac{1}{4}''$ inside, $7\frac{1}{16}''$ outside	
Weight of machine,	1470
Number of commutator bars,	50
Turns in one coil,	2
Length of useful wire in a coil,	48″
Must brushes be adjusted?	yes.
Diameter of bearing,	$1\frac{1}{2}''$
Length of bearing,	$6\frac{1}{4}''$
Turns per minute,	1600
Volts for best work,	125
Ampères for best work,	80

Table V gives the results of the measurements:

This machine was not coupled directly to the dynamometer, the high speed required being deemed unsafe. It was run by a belt from a pulley on the transmission shaft of the dynamometer. In allowing for the loss due to the belt, it was assumed that for the full load the friction of the armature was the same as that of the No. 5 dynamo.

The full load tests agree very closely, the total efficiencies increasing slightly with the horse-power. The commercial efficiencies differing very little.

The measurements on the partial loads are perhaps a little low, as it is probable that sufficient allowance was not made for the belt. The temperature was much lower than for the full load tests and the belt was probably stiffer.

TABLE V.—(*Edison No. 4 Dynamo.*)

DATE.	June 16th.				June 17th.			
Time,	2·16	3.30	4·25	5·20	11·00	12·15	2·15	2·40
Load,	Full.	Full.	Full.	Full.	¼	½	¾	Full.*
E. M. F. at terminals,	120·05	124·95	125·20	126·75	128·66	128·77	128·39	131·17
Total E. M. F., . .	124·64	129·61	129·97	131·91	130·00	131.09	132·22	137·08
Current in ext. circ.,	72·919	75·93	76·12	82·10	22·36	39·55	63·58	90·68
Current in field, . .	1·915	2·244	2·211	2·321	1·940	2·082	2·222	2·647
External resistance, .	1·646$_d$	1·646$_d$	1·647$_d$	1·543$_e$	5·755$_e$	3·256$_d$	2·019$_e$	1·446$_e$
Armature resistance,	·c614	·0596	·0610	·0611	·0550	·0556	·0582	·0634
Field, with box, . .	62 68	55·68	56·63	54·58	66·33	61·85	57·78	49·55
Field, alone, . . .	44·17	44·46	44·69	44·59	40·42	41·21	42·29	. . .
Power applied, . .	13·284	14·383	14·442	15·786	5·050	8·168	12·517	18·053
Total elect. energy, .	12·51	13·60	13·64	14·93	4·237	7·322	11·67	17·17
Ext. elec. energy, .	11·746	12·73	12·77	13·95	3·859	6·833	10·95	15·96
Energy in arm., . .	·461	·488	·501	·584	·0436	·129	·338	·741
Energy in field, . .	·309	·376	·371	·394	·335	·360	·382	·466
Total efficiency, . .	94·21	94·53	94·47	94·58	83·89	89 65	93·26	95·09
Commercial efficiency	88·42	88·52	88·43	88·38	76·40	83·65	87·50	88·40
Economic coefficient,	93·85	93·64	93·61	93·45	91·07	93·32	93·82	92·97
% of power in arm., .	3·47	3·40	3·47	3·70	·86	1·59	2·70	4·10
% of power in field, .	2·32	2·61	2·57	2·49	6·63	4·41	3·06	2·58
No. revolutions, . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Friction of arm., . .	·14	·14	·14	·14	·16	·16	·16	·16
Temp. of air, . . .	35·5° C.	36·5° C.	36·2° C.	36·° C.	21·° C.	23·° C.	25·° C.	24·8° C.
Temp. of pole-end, .	45·8° C.	45·5° C.	46·1° C.	45·5° C.	27·2° C.	29·5° C.	33·3° C.	34·6° C.

* Unofficial.

EDISON NO. 20 DYNAMO.

Diameter of armature,	$9\frac{1}{16}$ inside, $10\frac{5}{8}$ outside.
Weight of machine,	8331 pounds.
Number of commutator bars,	44
Turns of wire in a coil,	1
Length of useful wire in a coil,	59″
Must brushes be adjusted?	yes.
Diameter of bearing.	$2\frac{5}{8}$″
Length of bearing,	$10\frac{7}{8}$″
Number of turns per minute,	1000
Volts for best work,	125
Ampères for best work,	400

Table VI gives the results of the measurements:

The full load tests are marked unofficial, because the preliminary run of ten hours was not on full load. The machine was started at the usual time, midnight, with about the right load, but in a few hours the power fell to about fifty horse-power, and remained about the same until noon of June 19th, when by increasing the number of revolutions, the proper load was nearly attained. The tests were to have been repeated the next day, but unfortunately the insulation of the armature gave way, making this impossible.

The tests seem to agree quite well. It is hard to compare the first full load measurement with the others as the conditions were different. The two full load measurements made under about the same conditions agree almost exactly.

TABLE VI.—(*Edison No. 20 Dynamo.*)

DATE.	June 18th.			June 19th.			
Time,	1·00	2·25	3·50	9·45	1·30	2·45	4·00
Load,	¼	½	¾	Full.*	Full.*	Full.*	Armature insulation gave way.
E. M. F. at terminals,	126·16	122·0	123·99	105·95	125·04	125·4	
Total E. M. F., . .	127·46	124·10	127·55	110·00	129·60	129·95	
Current in ext. circ.,	100·22	192·46	291·16	330·88	387·28	379·00	
Current in field, . .	4·942	4·915	5·124	4·397	5·136	5·124	
External resistance, .	1·258$_d$	·6338$_d$	·4161$_d$	·3202$_d$	·3229$_d$	·3308	
Armature resistance,	·0124	·0106	·0120	·0121	·0116	·0119	
Field, with box, . .	25·53	24·82	24·20	24·10	24·35	24·47	
Field, alone. . . .	. . .	. . .	. . .	. . .	. . .	. . .	
Power applied, . .	20·254	35·43	53·11	51·06	70·72	69·39	
Total elec. energy, .	17·985	32·86	50·71	49·48	68·25	66·97	
Ext. elec. energy, .	16·965	31·50	48·44	47·04	64·99	63·76	
Energy in arm., . .	·1838	·556	1·416	1·82	2·40	2·35	
Energy in field, . .	·837	·809	·852	·625	·862	·862	
Total efficiency, . .	88·80	92·77	95·46	96·91	96·51	96·52	
Commercial efficiency	83·76	88·93	91·19	92·11	91·90	91·89	
Economic coefficient,	94·33	95·86	95·53	95·06	95·22	95·21	
% power in arm., .	·91	1·57	2·66	3·57	3·39	3·38	
% power in field, . .	4·13	2·27	1·61	1·23	1·22	1·25	
No. revolutions, . .	1008·9	1023·9	1008·8	1022·3	1092·1	1090·2	
Friction of arm., . .	. . .	. . .	. . .	·393	·393	·393	
Temp. of air. . . .	28·5° C.	28·5° C.	28·5° C.	31·5° C.	33·° C.	33·5° C.	
Temp. of pole-piece,	35·0° C.	37·8° C.	38·3° C.	44·5° C.	45·° C.	47·8° C.	

WESTON NO. 6 W. I. DYNAMO.

Diameter of armature,	8¼″
Weight of machine,	2100 pounds
Number of commutator bars,	56
Total number of turns in armature coils,	112
Turns per commutator segment,	2
Average length,	6 feet, 3½″
Must brushes be adjusted?	slightly
Diameter of bearing, pulley end,	1⅝″
Diameter of bearing, commutator end,	1⅜″
Length of bearing, pulley end,	6¾″
Length of bearing, commutator end,	5″
Turns per minute,	1200
Volts for best work,	130
Ampères for best work,	100

Table VII gives the results of the measurements:

The values of the total efficiency for the different measurements of this machine differ widely. The first test gives a much smaller value than the rest, and is rejected, because, whether the difference is caused by errors in the measurements, or in the adjustment of the machine, the test evidently does not represent the normal efficiency of the dynamo.

TABLE VII.—(*Weston No. 6 W. I. Dynamo, 130 Volts*).

DATE.	June 22d.			June 23d.			
Time,	. . .	2·00	12·40	2·20	3·35	4·35	5·35
Load,	¼	½	Full.*	Full.	Full.	Full.	¾
E. M. F. at terminals,	125·06	124·29	128·45	129·00	124·8	131·8	133·7
Total E. M. F., . .	126·17	126·34	133·12	133·87	129·89	136·22	137·19
Current in ext. circ.,	25·51	46·19	108·94	109·29	114·2	98·33	81·99
Current in field., . .	2·051	2·144	2·239	2·213	2·171	2·272	2·242
External resistance, .	4·901$_d$	2·691$_d$	1·180$_d$	1·180$_d$	1·093	1·340	1·630
Armature resistance,	·0404	·0424	·0420	·0437	·0438	·0439	·0441
Field, with box, . .	60·96	57·96	57·37	58·28	57·51	58·01	59·62
Field, alone, . . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Power applied, . .	5·092	8·820	20·98	20·71	21·01	19·28	16·48
Total elec. energy, .	4·666	8·193	19·86	20·03	20·29	18·39	15·50
Ext. elect. energy, .	4·281	7·703	18·78	18·92	19·13	17·39	14·70
Energy in arm., . .	·0412	·1329	·697	·729	·795	·596	·394
Energy in field, . .	·344	·358	·386	·383	·364	·402	·402
Total efficiency, .	91·64	92·89	94·68	96·69	96·53	95·39	94·06
Commercial efficiency	84·07	87·32	89·51	91·32	91·02	90·21	89·22
Economic coefficient,	91·74	94·01	94·54	94·45	94·29	94·57	94·86
% power in arm., .	·81	1·51	3·32	3·52	3·78	3·09	2·39
% power in field, . .	6·76	4·05	1·84	1·85	1·73	2·09	2·44
No. revolutions, . .	1167·2	1168·3	1258·5	1267·6	1250·6	1257·6	1252·3
Friction of arm., . .	. . .	. . .	. . .	·13	·13	·13	·13
Temp. of air, . . .	31·° C.	31·° C.	27·5° C.	27·5° C.	25·° C.	25·7° C.	. . .
Temp. of pole-piece,	35·° C.	37·° C.	35·5° C.	35·5° C.	36·7° C.	36·7° C.	. . .

* Rejected.

Table VIII gives a summary of the tests:

TABLE VIII.—(*Table of Efficiencies.*)

	Volts.	Ampères.	Weight.	Total Efficiencies. Full Load.‡	¾ Load.	½ Load.	¼ Load.	Commercial Efficiencies. Full Load.‡	¾ Load.	½ Load.	¼ Load.
Edison, No. 4, . .	125	80	1,470 lbs.	94·45	93·26	89·65	83·89	88·44	87·40	83·65	76·40
Edison No. 5,* . .	125	100	2,475 lbs.	96·01	. .	. .	. .	89·19	. .	. .	. .
Edison No. 10, . .	125	200	4,710 lbs.	94·68	92·44	90·55	83·32	89·61	88·23	86·12	77·53
Edison No. 20,* . .	125	400	8,331 lbs.	96·65†	95·46	92·77	88·80	91·96†	91·19	88·93	83·76
Weston 6 M., . . .	120	80	2,000 lbs.	94·67	96·53	94·84	89·33	87·66	90·10	89·23	82·87
Weston 7 M., . . .	160	125	3,300 lbs.	96·56	96·38	94·84	90·08	89·37	90·49	89·57	84·37
Weston 6 W. I., . .	130	100	2,100 lbs.	96·20	94·06	92·89	91·64	90·85	89·22	87·32	84·07

* Armature insulation gave way.
† Unofficial.
‡ Average of full load measurements.

In the table, the full load efficiencies of the Edison No. 20 dynamo are marked "unofficial," because the preliminary run was not in conformity with the code, not because there is any reason to mistrust the results.

Of the fifty-four measurements made, four were for obvious reasons deemed unworthy of calculation. These were two tests of the Edison No. 5 dynamo, and a couple of partial load tests of the Weston No. 7 M machine, made while the constant of the potential galvanometer was unsteady. Of the remaining fifty tests, but one is rejected—a full load measurement of the Weston 6 W. I. dynamo.

Considering the care taken in standardizing all of the instruments used in the measurements, and the very close agreement of tests made on the same dynamo, it seems probable that the results given in the above table represent very nearly the efficiencies of the machines under the conditions of the tests.

The dynamos were favored by being coupled directly to the dynamometer, and it will be seen on looking at the tables that the loss by friction was slight.

In the measurements, the ohm was taken at 106 centimetres of mercury, so in order to reduce the values to absolute measure the potentials, and, therefore, the efficiencies, should be reduced by about one-fourth per cent.

LOUIS DUNCAN, *Chairman.*
GEO. L. ANDERSON, *Secretary.*
WM. D. MARKS,
J. B. MURDOCK,
A. B. WYCKOFF.

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA

FOR THE

PROMOTION OF THE MECHANIC ARTS.

MECHANICAL AND ELECTRICAL TESTS

OF

Conducting Wires.

Report of a Special Committee, appointed by the President of the Franklin Institute in conformity with a Resolution of the Board of Managers, passed November 12, 1884.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, NOVEMBER, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE.
1885.

EDITING COMMITTEE.

PERSIFOR FRAZER, *Chairman*,
CHARLES BULLOCK,
THEO. D. RAND,
COLEMAN SELLERS,
WILLIAM H. WAHL

FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA.
FOR THE PROMOTION OF THE MECHANIC ARTS.

MECHANICAL AND ELECTRICAL TESTS OF CONDUCTING WIRES

To the Board of Managers of the FRANKLIN INSTITUTE:

GENTLEMEN:—I herewith transmit the report of the Committee, consisting of Lieut. George L. Anderson, U. S. A., for the electrical tests, and Mr. J. W. Grant, Engineer of Tests (Fairbanks & Co.), for the mechanical tests, appointed under authority of the resolution of the Board, adopted November 12, 1884, to conduct examinations and tests of conducting wires exhibited at the Electrical Exhibition.

Very respectfully,

W. P. TATHAM, *President.*

PHILADELPHIA, September 3, 1885.

MR. WILLIAM P. TATHAM,

President of the FRANKLIN INSTITUTE, *Philadelphia:*

SIR:—I have the honor to transmit herewith the results of electrical tests made on various kinds of wires, sent for trial to the Philadelphia Electrical Exhibition of 1884. The data contained in the left half of the sheet were copied from the labels found attached to the coils of wire, and in two or three instances it will be seen that the number of the gauge does not agree with the diameter measured. It is thought, therefore, that some of the labels may have been misplaced before the coils reached the FRANKLIN INSTITUTE. The figures in the right half of the sheet were those obtained from measurement. The length given in column VI is that portion of the coil of which the resistance was measured, and which is given in column VIII.

I am, very respectfully, your obedient servant,

GEORGE L. ANDERSON, U. S. A.

NEWPORT, R. I., July 19, 1885.

Electrical Conductivity of Wires sent to International Electrical Exhibition, Philadelphia, 1884.

Marks found on Labels tied to the Coils.					Measurements Taken and Computed.					
I. Gauge Number.	II. Gauge Name.	III. Description.	IV. Metal.	V. Name of Company Sending.	VI. Length of Coil in Feet.	VII. Diameter of Wire in Inches.	VIII. Measured Resistance of Piece or Coil in B. A. Ohms at 75° F.	IX. Resistance of 1,000 feet of Same.	X. Per cent. of Conductivity Referred to Soft, Pure Copper, at 75° F.*	REMARKS.
12	B W G	Bare, hard drawn	Copper,	Bridgeport Brass Co., Bridgeport, Conn.,	1398·	·109	1·289	·9221	97·3	
14	B W G	Bare, hard drawn	Copper,	Bridgeport Brass Co., Bridgeport, Conn.,	2050·	·083	3·259	1·590	97·3	
12	B W G	Bare, hard drawn	Copper,	Holmes, Booth & Haydens, New York,	131·4	·083	·212	1·612	96·0	
8	F B B	Bare, telegraph	Iron,	Washburn & Moen Mfg. Co., Worcester, Mass.,	52·8	·157	1·661	31·455	13·75	
8	F B B	Bare, telegraph	Iron,	Washburn & Moen Mfg. Co., Worcester, Mass.,	52·8	·159	1·620	30·668	13·75	
14	. . .	Bare, hard drawn	Telegraph copper,	Washburn & Moen Mfg. Co., Worcester, Mass.,	52·8	·084	·0829	1·570	96·2	
14	. . .	Bare, hard drawn	Telegraph copper,	Washburn & Moen Mfg. Co., Worcester, Mass.,	52·8	·084	·083	1·571	96·1	
14	B W G	Bare, soft drawn	Telegraph copper,	Washburn & Moen Mfg. Co., Worcester, Mass.,	52·8	·083	·084	1·591	97·2	
12	. . .	K. K. patent	Ins. Tel. iron	Holmes, Booth & Haydens, New York,	Insul. re sistance		100 ft. —	12×10^6	ohms.	
16	B W G	Patent finish painted	Electric light, copper,	Holmes, Booth & Haydens, New York,	Insul. re sistance		100 ft. —	9×10^6	ohms.	
14	B W G	Cotton cov. single wound	Copper,	Holmes, Booth & Haydens, New York,	87·8	·083	·140	1·594	97·2	
14	B & S G	Cotton cov. single wound	Magnet copper,	Holmes, Booth & Haydens, New York,	62·3	·0641	·1663	2·669	97·2	
16	B W G	Patent finish painted	Electric light, copper,	Holmes, Booth & Haydens, New York,	57·5	·0508	·2446	4·254	97·1	
16	B & S G	Cotton cov. single wound	Magnet copper,	Holmes, Booth & Haydens, New York,	55·	·0508	·2337	4·25	97·2	
14	B & S G	Cotton cov. single wound	Magnet copper,	Holmes, Booth & Haydens, New York,	44·5	·0641	·1186	2·666	97·3	
13	B & S G	Cotton cov. double wound	Magnet copper,	Holmes, Booth & Haydens, New York,	72·5	·072	·153	2·112	97·4	
14	B & S G	Cotton cov. single wound	Magnet copper,	Holmes, Booth & Haydens, New York,	48·0	·083	·0763	1·59	97·3	
10	B & S G	Cotton cov. single wound	Magnet copper,	Holmes, Booth & Haydens, New York,	35·	·134	·0214	·6101	97·3	
6	B & S G	Cotton cov. single wound	Magnet copper,	Holmes, Booth & Haydens, New York,	52·8	·162	·022	·4175	97·3	
6	B & S G	Cotton cov. double wound	Magnet copper,	Holmes, Booth & Haydens, New York,	48·3	·162	·02016	·4175	97·3	
12	B W G	Magnet covered	Copper,	Holmes, Booth & Haydens, New York,	43·5	·134	·0267	·6695	97·4	

* The resistance of one mill-foot of soft pure copper wire is taken as 10·66 B. A. ohms, at 75° Fahr.

PHILADELPHIA, August 31, 1885.

MR. WM P. TATHAM, *President of the* FRANKLIN INSTITUTE.

SIR :—I transmit the following results of mechanical tests of wire submitted.

Gauge No.	Description.	Company Sending	Diameter in.	Broke at in Pounds.	Average.	Elongation. Per Cent. in 12 inches.	Average.
No. 12, B W G	Hard drawn copper wire,	Bridgeport Brass Co., Conn.,	·108	680	. .	1·2	. .
	Hard drawn copper wire,	Bridgeport Brass Co., Conn.,	·108	675	677·5	1·3	1·25
No. 14 B W G	Hard drawn copper wire,	Bridgeport Brass Co., Conn.,	·083	301*	. .	1·4	. .
	Hard drawn copper wire,	Bridgeport Brass Co., Conn ,	·083	305*	303·	1·2	1·3
No. 8, F B B	Iron telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (1)	·157	1225	. .	10·1	. .
	Iron telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (1)	·157	1236	1230·5	11·	10·55
No. 8, F B B	Iron telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (2)	·158	1224	. .	11·9	. .
	Iron telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (2)	·158	1230	1227·	12·	11·95
No. 14,	Hard drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (1)	·084	325	. .	·52	. .
	Hard drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (1)	·084	329	327·	·52	·52
No. 14,	Hard drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (2)	·084	349	. .	·26	. .
	Hard drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass , (2)	·084	344	346·5	·24	·25
No. 14, B W G	Soft drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass , (1)	·083	205	. .	29·7	. .
	Soft drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass , (1)	·083	206	205·5	30·2	29·95
No. 14, B W G	Soft drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (2)	·082	204	. .	28·1	. .
	Soft drawn copper telegraph wire,	Washburn & Moen Mfg. Co., Worcester, Mass., (2)	082	204	204·	31·7	29·9

* These pieces were taken from a coil which had been used as a conductor during the tests at the Electrical Exhibition.

Two specimens taken from each coil.

Yours respectfully,

JAMES W. GRANT.

THE FOUNTAIN.

1884—INTERNATIONAL ELECTRICAL EXHIBITION—1884

OF THE

FRANKLIN INSTITUTE, OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

GENERAL REPORT

OF THE

CHAIRMAN

OF THE

COMMITTEE ON EXHIBITIONS.

[ISSUED BY AUTHORITY OF THE BOARD OF MANAGERS AND PUBLISHED AS A SUPPLEMENT TO THE JOURNAL OF THE FRANKLIN INSTITUTE, JULY, 1885.]

PHILADELPHIA:
THE FRANKLIN INSTITUTE
1885.

INTERNATIONAL ELECTRICAL EXHIBITION, 1884.

FRANKLIN INSTITUTE, Philadelphia, Pa.

To the Board of Managers, Franklin Institute:

GENTLEMEN:—I have the honor to present herewith a General Report—Historical and Descriptive—of the International Electrical Exhibition.

Respectfully,

CHARLES H. BANES,

Chairman of the Committee on Exhibitions.

PHILADELPHIA, *March*, 1885.

GENERAL REPORT OF THE CHAIRMAN OF THE COMMITTEE ON EXHIBITIONS.

FORMER EXHIBITIONS.

The Franklin Institute was founded in 1824, for the purpose of promoting the mechanic arts. It has progressively carried out the intention of its founders by means of courses of popular scientific lectures, schools for drawing, experimental tests of new inventions, by work of original research in its laboratories, and through the Committee on Science and the Arts. In addition to this, exhibitions of manufactures and processes in the arts have been given at various periods in the history of the Institute, commencing at a very early date. These displays have attracted throngs of visitors and have always been anticipated by our citizens with a great deal of interest. The last of these, prior to that of 1884, was held in 1874, and proved equally attractive as those preceding, and was in every way a successful one.

Since the close of the Centennial Exhibition in 1876, the Institute has taken no part in any display of the mechanic arts, being deterred from doing so, partly on account of the overshadowing influences of its magnitude and more especially for the reason that Philadelphia, the city noted for its skilled mechanics and extensive industries, contains no available structure that can be used for a collective exhibition representing their varied work.

ORIGIN OF THE EXHIBITION.

The recent Electrical Exhibitions held by France, England, Germany and Austria, impressed the committee on Exhibitions with the fact that electricity, in its applications, had long since passed from the experimental period to that of permanence and practical necessity, and is to-day attracting a large share of public attention. Influenced by this thought the Chairman of the Committee on Exhibitions suggested to the Board of Managers of the Franklin Institute, at their meeting,

December 13, 1882, "That the Institute should take steps to hold an exhibition of electric lighting and of the machinery pertaining thereto." The proposition was referred to the committee, and after due consideration the following was presented to the Board, February 14, 1883:

"*Resolved*, That in the opinion of the Committee on Exhibitions it would be both practicable and advantageous for the Franklin Institute to organize an International Exhibition of Electrical Subjects, to be held in Philadelphia in the near future, and the committee so recommend."

The recommendation of the committee was approved and authority given to select a place and appoint a time for holding the exhibition.

At a meeting of the Board, held March 14, 1883, a resolution was passed enlarging the committee until it embraced all the Managers of the Institute, and subsequently the number was further increased by authority given the chairman to appoint on the committee members of the Institute who were not on the Board of Managers.

GUARANTEE FUND.

To secure the Institute from pecuniary loss, it was deemed advisable to "raise an adequate guarantee fund to protect the interests of the Franklin Institute." A proper form was prepared for this paper and its circulation resulted in pledges from public-spirited citizens to the amount of $37,370.

ACT OF CONGRESS.

Simultaneous with this movement, Mr. William P. Tatham, President of the Institute, addressed a communication to the Congressmen from Philadelphia, asking that steps should be taken before the adjournment of Congress to authorize the admission of foreign goods intended for the exhibition without the payment of customs duties. This request met with a prompt response and led to the passage of a joint resolution which was approved February 26, 1883. Soon after this action by Congress, Hon. Charles J. Folger, Secretary

of the Treasury, issued a circular dated March 22, 1883, giving specific instructions to the "Collectors of Customs and others" as to its interpretation. Although these instructions were in many respects similar to those heretofore issued in reference to International Exhibitions, the provisions were construed by the committee as unfavorable to the prompt admission of foreign goods. Proper representations were made to the Secretary of the Treasury, and attention called to the fact that a large part of the importations would comprise instruments not made in this country, and especially valuable for the uses of colleges and scientific institutions. This led to the issuing of a circular, dated November 14, 1883, giving more liberal and entirely different orders whereby the difficulty was removed. Under the new orders the business of receiving and entering imports was greatly facilitated, and at the same time the United States Government was amply protected. The buildings were made bonded warehouses and security was entered in the sum of $40,000 by Charles H. Banes, Dr. Persifor Frazer, and the President of the Institute.

SITE FOR THE BUILDING.

In the progress of preparations, one of the first difficulties encountered was the selection of a proper and suitable location for the erection of a building, After considering a number of properties and encountering as many disappointments, the difficulty was met by the liberality of the Pennsylvania Railroad Company in the offer, upon nominal terms, of the lease of a vacant lot of ground belonging to that company situated between Thirty-second and Thirty-third streets, and Lancaster avenue and Foster street, Philadelphia, containing 66,645 square feet. This proposition was made through Mr. William Sellers, a member of the Board, and at the same meeting, June 13, 1883, it was unanimously accepted and arrangements made for the preparations of a lease. This was authorized to be signed December 12, 1883.

BUILDING PLANS.

Preparations for plans of the buildings to be erected were commenced by Mr. Joseph M. Wilson, who was appointed Architect, by the Board. To increase the available space and to secure a location outside the main building for the steam boilers, authority was asked from the City Councils to occupy Foster street for the purposes of the exhibition and an ordinance was passed to this effect and approved by the Mayor. The additional space thus secured was of great advantage to the Exhibition, and at once solved the question of the proper disposition of the large amount of power required for the engines and dynamos. The plans, as submitted by the architect, were approved January 9, 1884. After proper advertisement, the contract was awarded to Jacob R. Garber, the lowest bidder, for the sum of $29,628. During the progress of the building operations, it was deemed advisable to extend the width of the north and south galleries in the main building, and to erect a large fountain to be illuminated with electric lights, and to make other changes not contemplated in the original specifications. These alterations greatly increased the cost of the structures.

To provide the necessary means for completing this work, and to meet payments promptly as they became due, the following was passed by the Board of Managers, February 29, 1884:

"*Resolved*, That the President and Treasurer (of the Franklin Institute) be authorized to borrow the sum of forty thousand dollars, at such times and in such sums as may be found necessary to pay for the erection of the buildings and furnishing the same, and for the preliminary expenses of the proposed Electrical Exhibition to be held under the auspices of the Franklin Institute, and that for any money which may be borrowed, the President and Treasurer be, and they are hereby authorized to issue the promissory notes of the Franklin Institute, payable at such times as may be agreed upon with the lender or lenders of the money so borrowed and to secure the payment of the same by pledging as collateral security for such payment any bonds, loans, or stock owned by the Institute, and for any such pledges to make such transfers and assignments as may be required."

ADVERTISEMENTS.

The sub-committees on Space and on Publication, commenced active work in January, 1884. "Rules and Regulations," "Application for Space" and "Information for Exhibitors," were prepared and printed in English, German, French and Italian and were mailed to parties interested in electrical matters in the United States and foreign countries. The subject was also brought directly to the attention of foreign governments through the courtesy of Hon. F. T. Frelinghuysen, Secretary of State of the United States.

To give further publicity to the exhibition, and especially to inform the general public of the progress of preparations and awaken interest in electrical matters, a semi-monthly paper, edited by the Chairman of the Exhibition Committee, aided by his associates, was published on the 1st and 15th of each month, commencing June 2, 1884, and continuing until the close of the exhibition. Files of this Journal, the "Bulletin of the International Electrical Exhibition," preserved in the Library of the Institute, furnish a record of value as a narration of the progress of the work of the committees, together with many papers of value and merit, written by specialists, upon electricity, magnetism, and collateral subjects. The circulation of the "Bulletin" amounted to over 2,000 copies for each edition, and these were distributed free to colleges, libraries and scientists in various localities throughout the United States and Canada. The paper became very popular and copies were sought after by persons from all sections.

In addition to the publicity given to the exhibition by means of the distribution of official printed matter, a comprehensive scheme for advertising was devised by the Committee on Correspondence and Publication, and through a special committee, of which G. Morgan Eldridge and Jules Viennot were exceedingly active members. In the execution of this plan, lithographs of the buildings were through the courtesy of the railroad officials, placed in every important depot and station on the Pennsylvania and the Reading railroads, and their connections. Thousands of these lithographs were also distributed by the

EXHIBIT OF THE EDISON COMPANIES.

merchants of Philadelphia, through their correspondents. Printed circulars and programmes were mailed to large numbers of newspapers and private schools, and also placed in prominent hotels at summer resorts. Large posters, containing a picture of the buildings and annex, with date of opening of the exhibition, were displayed in conspicuous places in towns in Pensylvania, and the northern and western states. There was also a large amount of advertising done in many prominent daily papers and scientific journals. The work of this committee was very effective, marked by great enterprise, and beyond doubt added largely to the receipts from visitors. In this connection it is proper to acknowledge the invaluable assistance that was rendered by all the daily newspapers of our city, and scientific journals of this and other cities, especially the New York "Electrical World," the "Electrical Review," "The Electrician," and the "Scientific American," in frequent gratuitous notices of the progress and development of the exhibition. The "Philadelphia Record," devoted a large part of two editions to the exhibition, publishing a full page illustration of the building without cost to the Institute. The Philadelphia papers furnished without charge, copies of their daily issues to the reading room at the building. The

GENERAL CLASSIFICATION OF THE EXHIBITS,

and the synopsis of the same, was prepared by a sub-committee of which Prof. Pliny E. Chase, of Haverford College, was chairman. Especial attention is called to the work of this committee, on account of the labor performed and the fidelity with which it discharged a duty requiring much thought and study as well as familiarity with the productions and applications of electricity. The work has been highly commended by scientists and experts, and is in itself a complete index of electrical progress, as recorded in the literature of the subject at at the date of the exhibition.

SUPERINTENDENT AND ELECTRICIAN.

In April, 1884, Prof. William D. Marks, of the University of Pennsylvania, accepted the position of General Superintendent, and Prof. Edwin J. Houston, of the Central High School, Philadelphia, that of Electrician. These gentlemen brought to the duties of their positions that energy, enthusiasm and special fitness that tended so largely to the success of the exhibition. They were untiring in their efforts, and under circumstances of unusual difficulty commanded the respect of those with whom they came in contact.

For the purpose of securing the highest possible safety, both to life and property, a Committee for the Installation of Electrical Apparatus was appointed, consisting of Prof. Edwin J. Houston, Chairman, Henry Morton, Charles M. Cresson, M. D., W. P. Tatham and M. B. Snyder. A code of carefully prepared rules was adopted, and exhibitors were requested to give their co-operation in carrying them into effect.

These rules were carried into effect under the able personal direction of the Electrician, Prof. Edwin J. Houston. Their actual application demanded constant and untiring attention on the part of the Electrician and his assistants, so as to meet the requirements of particular cases as they arose. Not only electrical skill, but practical knowledge was required in order to safely conduct through a frame building the intricate net work of wires to supply the various exhibits. The able manner in which this was accomplished even in its minutest details, is witnessed by the fact that although many of the arc light circuits had an electro-motive force of as high as 3,000 or 3,500 volts, no single accident to life, or alarm of fire, occurred in the buildings during the entire period of the exhibition.

The circuits were tested daily for "contacts" or "grounds" by Prof. Houston, or by his assistant Mr. Carl Hering, and all causes of danger removed before the current was permitted in them.

Mr. Hering, the assistant electrician, rendered valuable and able services not only to the Electrician in aiding the testing and the location of the various circuits in the building, but also to the committees

appointed by the Institute for making tests and measurements. He was specially fitted for these duties by his laboratory experience and the information acquired during the Vienna Electrical Exhibition of 1883, where he officially represented the Franklin Institute. The

ARRANGEMENTS FOR THE EXTINGUISHMENT OF FIRES

were very complete and worthy of notice. The fire patrol consisted of men from the Philadelphia Fire Department, assigned by authority of the Fire Commissioners and under the personal direction and control of Chief John R. Cantlin. These firemen were selected for their experience and fitness, and a detail was on duty continually, day and night. "The committee to procure appliances for the extinguishment of fire," was composed of Captain McDevitt, C. J. Hexamer, and William B. Cooper, aided by the counsel of Captain Stillman, of the Insurance Patrol. The principal reliance, in case of fire, was upon a chemical engine, loaned by Messrs. W. K. Platt & Co., of Philadelphia, and hand fire extinguishers.

The efficiency of the preparations was fully tested by the promptness with which the detail extinguished a fire that took place at midnight in the car sheds of the railroad adjoining the annex. This latter occurrence illustrates the dangers that may sometimes threaten electrical exhibitions located in proximity to railroad stations.

THE DETECTIVE AND POLICE FORCES

were well managed. The former was under the charge of Chief Samuel I. Givin, who was constantly on duty, and it is to his credit to state that there was entire freedom from robberies or the operations of pickpockets. The daily details of patrolmen from the city police force, to assist in preserving order, were kindly furnished by his Honor, William B. Smith, Mayor of Philadelphia, and the Institute is under obligations for the promptness and efficiency with which their services were rendered.

OPENING CEREMONIES.

The exhibition was opened at the time indicated in the advertisements, September 2, 1884. The ceremonies began in the building lately used as the station of the Pennsylvania Railroad, loaned to the Institute, and used as the Annex. It was connected with the main buildings by means of a bridge over Thirty-second street, and reached by a broad flight of stairs, leading from the north avenue of the station. The large waiting room had been extensively repaired and placed in complete order, a lecture platform and large screen for illustrations erected at the north end, and two special apartments set aside in the southern portion for historical and bibliographical displays. The recently bare walls were rendered attractive with very large maps of the hemispheres, upon which were shown the locations of the sub-marine cables and of the principal overland wires. These were executed in distemper by a prominent scenic artist of Philadelphia from designs collated by Prof. Houston. Above the Market street entrance, the wall was decorated with red, white and blue bunting. The front and sides of the platform were completely hidden from the audience by growing plants. The space above the rear of the platform was tastefully decorated with the national colors.

The invited guests, among whom were representatives of foreign governments, scientists and many distinguished citizens assembled in the lecture hall at noon. After an overture by the Germania Orchestra, Hon. George H. Boker, Chairman of the Committee on Ceremonies, introduced His Honor, Mayor Smith, who welcomed the guests to Philadelphia. The procession was then formed and moved across the bridge to the main building where thousands of people had already assembled. After prayer, by Rev. Dr. J. S. McIntosh, William P. Tatham, President of the Institute, delivered the opening address, and at its conclusion, introduced Governor Robert E. Pattison, who in well chosen words declared the exhibition open. At the touch of an electric button by the wife of Prof. Marks, the Superintendent, the

machinery started and electric lights flashed in every part of the large structure. The opening scene was one of great attraction and brilliancy.

COLLEGES AND SCHOOLS.

The preparations for the exhibition entailed a large amount of labor and responsibility upon the committees, occupying a period of several months, and this work by no means terminated at the day of opening. Impressed with the fact that foreign electrical exhibitions had been attended with pecuniary loss to the projectors, the committee determined to awaken a special interest in the colleges and schools of the country, for the purpose of inducing a large attendance of scholars as visitors. Nor was this motive entirely mercenary, for it became evident early in the preparations, that the educational facilities would be unsurpassed and ought not to be neglected. With this view, Mr. G. Morgan Eldridge, Chairman of sub-committee on schools, addressed communications to a large number of schools throughout the country, announcing the character and peculiar attractions of the exhibition, the arrangements made for transportation, and the reduced price of admission for schools visiting in a body. In response to a proposition made to the Board of Education of Philadelphia, the public schools of the city of the grade of high, normal, grammar, and unclassified, were granted each one day of vacation during the school term to attend the display. As the result of these arrangements, the official record of admissions, shows an attendance, as organizations, of 97 schools, with 740 teachers and 16,657 students. In addition to these formal visits, there was an attendance at different periods of a number of sections and single classes.

To facilitate the work of teachers in making the visits profitable to their pupils, arrangements were effected with professional men, familiar with electrical matters, to act as guides in explaining the uses of the machines, and the theories of electricity to the young visitors and without cost to them. This scheme proved of great value as a series of interesting object lessons.

A special inducement for study and observation of exhibits was

offered the scholars of the public schools in the offer of prizes, consisting of a five dollar gold piece, and an honorable certificate of the Franklin Institute for the best compositions upon the subject, "What I saw at the Electrical Exhibition." The number of prizes distributed amounted to eighty, of which sixteen were secured by the High and Normal schools, and the remainder by the Grammar and Unclassified schools. In addition to these awards, two special prizes of ten and fifteen dollars were added by the "Electrical World," of New York. These were distributed, with appropriate ceremonies, before a large audience assembled at the Normal School building, Thanksgiving night, Nov. 27, 1884.

The preparation for the plans to enlist the interest of the public schools and the laborious details incidental to the distribution of tickets, and the collection of the payment for the same, was voluntarily undertaken by Prof. James MacAllister, Superintendent of Public Schools, in Philadelphia. In addition to this work he also placed the committee under great obligations by his arrangements for, and personal attention to the selection of the prize compositions. In the discharge of this last duty Prof. MacAllister was ably assisted by Prof. Vogdes, of the High School, and by the Secretary of the Institute.

LECTURES.

To add still further to the educational attractions, arrangements were made for an excellent course of lectures, under the care of a committee appointed for the purpose. The report of the Chairman is annexed and will be found of interest, as illustrative of the high character of the lecturers in their various specialties. For the public schools, a special course upon electrical subjects was delivered by Prof. Houston. The school lectures were profusely illustrated and although necessarily elementary were exceedingly interesting and profitable. Two were given each day during the visits of the schools, covering a period of three weeks, and the close attention of large audiences was held during the time of delivery. Prof. Houston was greatly assisted in this work

by the liberality of Jas. W. Queen & Co. in furnishing, as a loan, a large variety of apparatus under the care of trained assistants. Valuable aid was also given in the illustration of electric currents by the Edison Co. This latter service required the special work of their large dynamo. Numerous testimonials to the value and usefulness of Prof. Houston's course have been received.

MUSIC.

To popularize the exhibition to those visitors who might not be attracted by a display confined entirely to a special science, and who desired amusement as well as instruction, concerts were given every afternoon and evening. The music was furnished by the Germania Orchestra, led by Prof. Charles M. Schmitz. In addition to this, organ recitals were given at stated periods, upon an organ operated from key boards, placed at a distance, by means of an electric action. The movement for the bellows was furnished by an Edison motor attached beneath. This instrument was loaned by H. L. Roosevelt, of New York, and was formerly in the New York Academy of Music.

FOUNTAIN.

Another important feature of popular attraction was the large fountain occupying the middle portion of the main building. From the flower banked borders of the basin, thirty feet in diameter, there issued twelve jets of water, the curved trajectory of the streams dashing in spray against a truncated cone of rock-work in the centre of the basin. From the apex of the cone there flowed a dome-shaped sheet and a convolvulus jet of water. To make an economical use of the large quantity of water required to continually supply these jets and streams, the basin was first filled, and afterward the same water was used over again for weeks without calling upon the service pipes of the city. This was successfully accomplished by the use of two steam pumps, capable of forcing 3,000,000 gallons per day, loaned by the Worthington Co. The beauty of this attraction was greatly enhanced

at night by electric illumination and prismatic changes of colors. To heighten the effect, the lights were extinguished in the great arch of 100 feet span, and the fountain presented a picture of marvellous beauty, first as flowing fire of different colors, then in the bright white of dazzling silver, quickly turning to softer rays with each change of the prism. The periods of illumination were announced by programmes and never failed to attract enthusiastic spectators. Numbers of people repeatedly visited the exhibition to witness this wonderful feature. The plan and construction of the fountain was under the personal superintendence of Prof. W. D. Marks, to whose good taste and energy the result was a fitting tribute.

PRIMERS OF ELECTRICITY.

To enable visitors to properly understand the names and uses of the machines and instruments on exhibition, a large number of placards and descriptive signs were placed about the building and attached to exhibits, giving in popular phrases their name and a brief description. In addition to this information a series of elementary papers called "Primers of Electricity," were written by Prof. E. J. Houston. These were printed on four and eight pages, illustrated, and were sold at a nominal price. Over eighty thousand were disposed of, and they became very popular and useful to visitors and young students. Notwithstanding the low price at which they were sold, they proved a source of considerable revenue to the Institute.

STEAM-POWER AND ENGINES.

At a very early period, in the preparations by the committee, the question of steam-power and engines to drive the dynamos demanded the serious consideration of the sub-committee having this matter in charge. Mr. Frederick Graff, a most efficient chairman, aided by Messrs. Washington Jones, Henry C. Davis, W. Barnet Le Van, and others, bestowed not only a great amount of labor in planning the work, but cheerfully gave valuable time in arranging with manu-

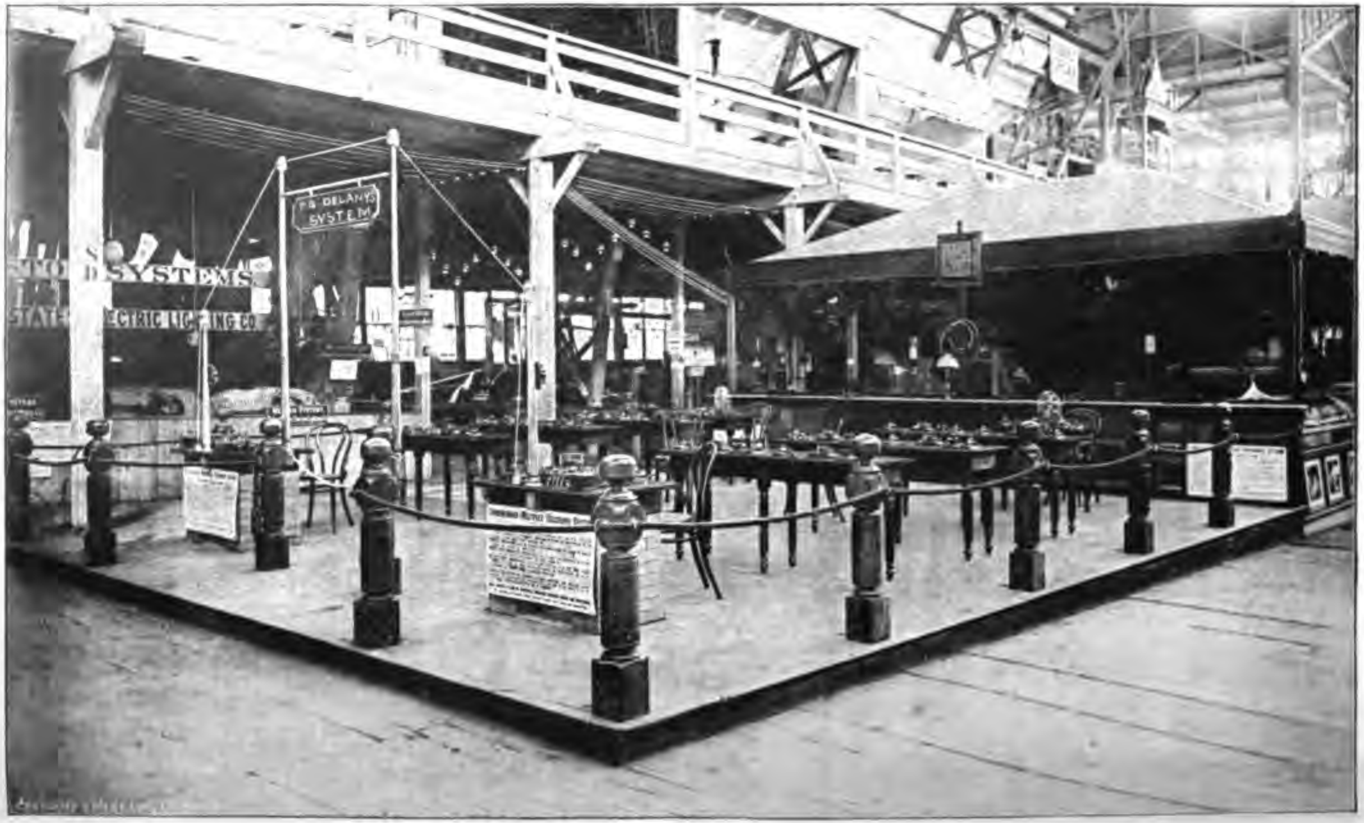


EXHIBIT OF DELANY'S SYNCHRONOUS-MULTIPLEX TELEGRAPH SYSTEM.

facturers to take part in the exhibit. From the time of opening until the close of the exhibition the boiler-house constructed of wood, with a corrugated iron roof, and occupying the entire length of Foster street, from Thirty-second to Thirty-third streets, was a place of great interest and was visited by a large number of people. Arrangements were made and successfully carried out, whereby visitors could examine any boiler in operation without being incommoded, as is often the case in similar exhibitions, by the annoyance of ashes, dust and leaky joints. The entire building devoted to the generation of steam was well arranged and ventilated, and with good lighting facilities. The total amount of 1,800 horse-power was furnished by four Babcock & Wilcox boilers, three Harrison, one Burnham, Parry, Williams & Co. (steel), two Abendroth & Root, one Dickson & Co., Scranton, Pa., and four locomotive boilers, two of these latter being furnished each by the Pennsylvania Railroad and Reading Company. With the exception of two of the Babcock & Wilcox, these boilers were loaned for use without charge, the exhibition furnishing fuel and expense of firing. The steam pumps supplying these boilers were loaned for use by Davidson Steam Pump Company, New York, and others.

Exhibitors were furnished with power, either from shafting driven by engines under the control of the committee, or steam was supplied directly to engines installed as part of individual or company exhibits. Among the former were those of the Southwark Foundry and Machine Co., Buckeye Co., Salem, Ohio; Kensington Engine Works, Philadelphia; Straight-Line Engine Co., Syracuse, N. Y., and New York Safety Steam Power Co. Some of these firms with others, mentioned in full in the catalogue and reports, supplied individual exhibits with power direct. With the collection of boilers and engines were many new and valuable appliances for the generation and economical use of steam. For a complete list reference can be had to the report of the Committee on Tests of Boilers and Engines. Without desiring to do injustice to other members of this special committee it is but proper to mention the intelligent and faithful work done by Mr. H. W.

Spangler, in charge of boiler and engine tests, and the able assistance rendered by Mr. Arthur L. Church, Superintendent of Power.

LOCATION OF EXHIBITS.

The sub-committee on space had many difficult problems to solve, and was without the experience gained by precedents, this being the first exhibition of strictly electrical matters held in this country. To do justice to the exhibitors, required the close personal attention of the chairman of this committee, Mr. Charles Bullock, who for several months preceding and during the exhibition neglected his private business in order that he might discharge the duty of locating exhibits. In spite of complex questions, arising from the novelty of the demands, the committee gave very general satisfaction. The charges for space and the rules governing the use of the same are contained in the annexed "rules and regulations."

DEPARTMENT OF ADMISSIONS.

The Department of Admissions was under the charge of Mr. Samuel Sartain, Treasurer, and Mr. Henry R. Heyl. The system devised and put in operation could scarcely be improved upon. The sub-committee consisted of Samuel Sartain, Henry R. Heyl, Dr. Isaac Norris, Jr., and William H. Wahl, and from their full and interesting report of detail on file in the Institute, the following extracts are made: "The price of admission was fixed at fifty cents for adults, children twenty-five cents, for pupils of the public schools of Philadelphia visiting by sections, fifteen cents, and for all other schools coming in a body, twenty-five cents. Teachers accompanying pupils of Philadelphia public schools were admitted free, and likewise one teacher with every fifteen pupils of other schools. During the third week of the exhibition the committee issued a special ticket for thirty-five cents, for sale in large quantities, to societies and industrial establishments. At the same time a form of ticket was issued containing ten coupons for three dollars and fifty cents. These were not good except detached by the turn-

stile keepers. The total number of admissions was 282,779. The cash sales of tickets amounted to $98,639.70. In addition to the schools, visiting in a body, there was a large number of other organizations, industrial and scientific, that attended the exhibition during its progress. Among the latter were the United States Electrical Conference, the American Association for Advancement of Science, the British Association for the Advancement of Science, the Royal Society of Canada, the American Institute of Electrical Engineers, the American Institute of Mining Engineers, the New York Electrical Society, the Agassiz Association, the Inter-Collegiate Association of Alumnae, and others. The committee acknowledge the courtesy of Messrs. Farrel & Co., who loaned without charge two commodious fire-proof safes, and Messrs. Westcott & Thomson, who donated all the electrotype plates for the production of tickets."

The number of visitors to the exhibition was largely increased by the enterprise of the Committee on Advertisement in their arrangements for excursions from towns in the interior. By this means, reduced railroad rates were secured and an interest awakened to the advantages presented. Several of these excursions came from towns over one hundred miles from Philadelphia, returning the same day to their homes.

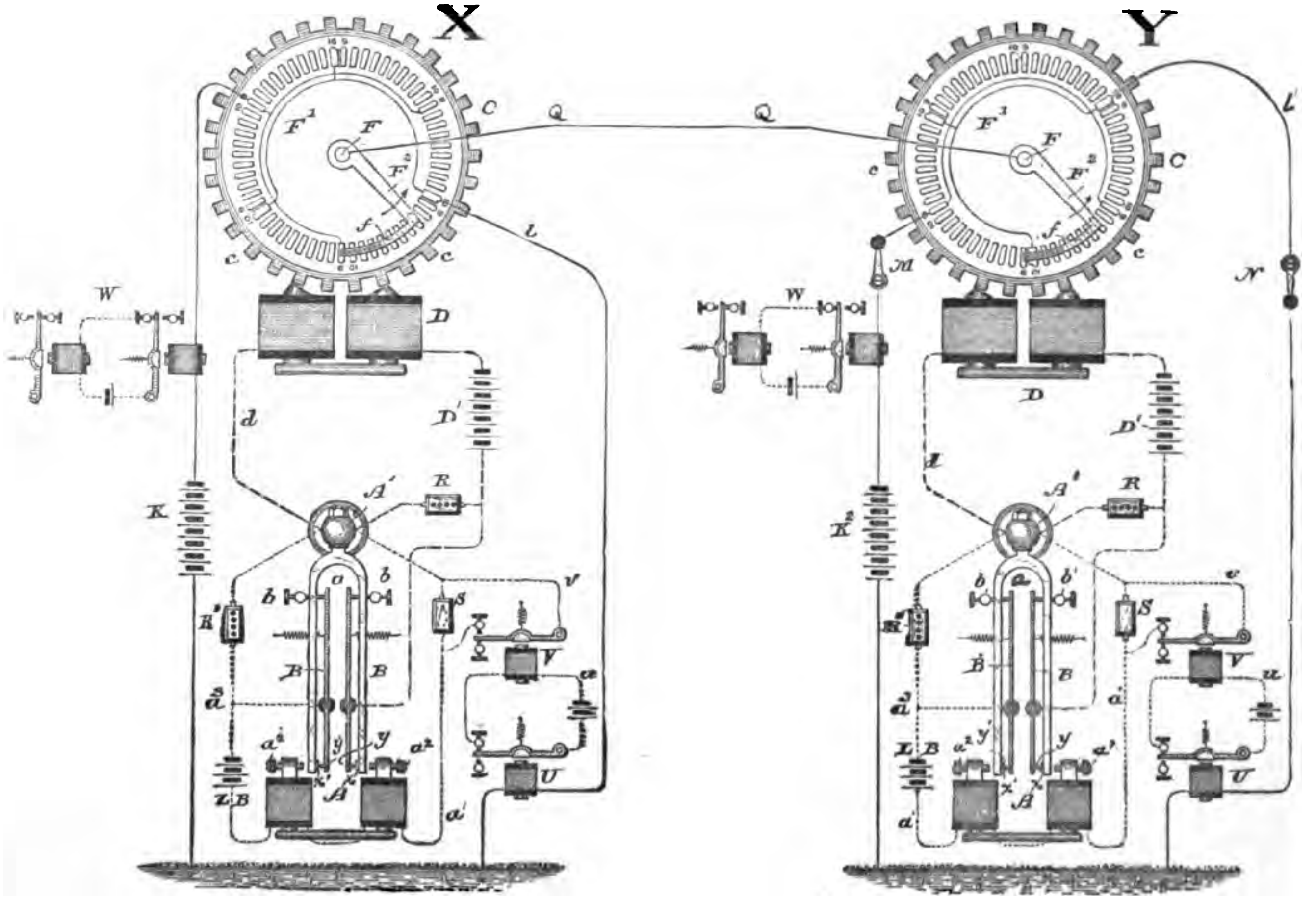
COMMITTEE ON BIBLIOGRAPHY.

The report of the Committee on Bibliography, charged with the special duty of preparing a collection of books and pamphlets relating to the subject of electricity and magnetism, shows as the result of their work a memorial library, consisting of volumes, bound and unbound, monographs and pamphlets, numbering 2,976. There was also contributed about one thousand dollars in cash. In soliciting the co-operation of English and Continental book publishers, the committee was favored with the valuable assistance of Mr. Frederick Ransome, member of Institute, residing in London, and Mr. Coleman Sellers, at the time in England, and a representative of the Franklin Institute, by invitation, to the ter-centenary of University of Edinburgh, and Mr. Leopold

Bossange, of Paris. This library, in accordance with the proposition contained in the invitation to doners, was formally presented to the Franklin Institute at the close of the exhibition. It will be preserved and increased as new books may be secured and will prove of great value for reference and study. The catalogues of books and subjects is well worthy of examination and was prepared with a great deal of care by Mr. E. Hiltebrand, Librarian. Dr. Isaac Norris, Jr., and his colleagues of the committee, Messrs. Wahl, Houston and De Motte, were indefatigable in pushing the work to the success it attained. In this connection it is proper to acknowledge the valuable services voluntarily rendered, not only as a member of this committee, but in other departments, especially that of lectures and historical display, by Prof. John B. De Motte, of DuPauw University, Greencastle, Indiana. The trustees of this institution kindly extended a leave of absence for several months to the Professor so that he might assist in the work of the Institute.

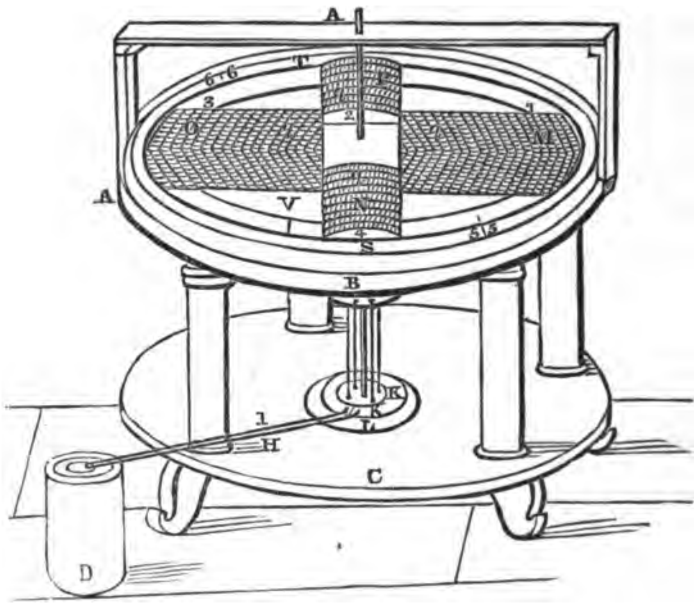
SPECIAL HISTORICAL EXHIBIT.

In order that the progress of electrical science might be traced from its earliest history, by visitors and students, it was deemed advisable to prepare a special historical exhibit. In the rooms set apart for this purpose many valuable machines and models, loaned in response to requests of the committee, were arranged, and attracted a great deal of attention. The historical report will present a list containing almost every invention of value in marking the development of electrical science. The most conspicuous, in extent was the exhibit of the United States Patent Office. Over two hundred models, many of them of rare interest, were arranged on tables and so labeled as to clearly indicate their title and purpose. A complete list appears in the catalogue, and the committee appreciate the kindness of the Commissioner of Patents, and Mr. C. J. Kintner examiner in electricity, manifested in the loan and preparation of this display. Many individuals and firms added interest to the collection by sending machines of value. Prominent



THE DELANEY SYNCHRONOUS-MULTIPLEX TELEGRAPHY.

among the latter was the exhibition of Messrs. Wallace & Sons, Ansonia, Conn., this firm forwarded nine machines, among them the magneto-electric telemachon, for the development of power at a distance from its source. This was used at the Centennial in 1876. In order that the Wallace machines could be supplied with power, they were assigned a special location in the main building. The Franklin Institute added to the interest of the collection by depositing some of the original Franklin apparatus.



Davenport's Electric Motor. (From Exhibit of U. S. Patent Office.)
Patented February 25, 1837.

No portion of the vast collection in the electrical exhibition afforded greater interest for the thoughtful than the historical display. So great has been the progress in improvement since the House telegraph patent of 1846, the electric light patents of 1861, and the telephone patents of a still later date, that the famous first message of Prof. Morse has become a fitting legend for electrical progress, "What hath God wrought!"

GOVERNMENT EXHIBITS.

From the beginning of the work the exhibition Committee had the cordial co-operation of the Executive and the heads of Departments of the Government. These efforts were restricted, however, by the want of funds. Congress, while appropriating large sums of money to exhibitions at New Orleans and other cities, did not see fit to assist the Philadelphia exhibition except by resolutions. This failure rendered it necessary for the Franklin Institute to bear the expense incidental to the transportation and installing of Government exhibits, and no money was spared to have the display made in a creditable manner. The following Departments were represented by interesting collections:

Ordnance Department, U. S. Army, in charge of Captain O. E. Michaelis.

Ordnance Department, U. S. Navy, in charge of Lieutenant Bradley A. Fiske.

U. S. Coast and Geodetic Survey, Treasury Department.

Smithsonian Institution.

U. S. Signal Office, in charge of Sergeant A. Eccard.

These exhibits embraced instruments of precision as well as electrical apparatus. An attractive feature in the contributions of the U. S. Navy was a search light of great power. This was mounted upon the north-east tower of the main building, and at night proved an object of great interest and wonder as its powerful rays of light illumined distant parts of the city. The thanks of the committee are due to the heads of Departments, and to the officers in charge for their efficient aid.

LIGHTING THE BUILDING AND GROUNDS.

The electric lights in the buildings were furnished proportionately, and without charge by all companies having dynamos on exhibition. The main arch and galleries were illumined by arc lights and the other portions of the main building by incandescent lamps. The lecture

room in the annex was exceedingly well lighted by the tasteful chandeliers of the Edison Company, the current being furnished by their large dynamo, popularly known as "Jumbo." The restaurant adjoining the lecture hall was lighted without cost to the exhibition by the Siemens Regenerative Gas Company. This latter arrangement was entered into for the purpose of affording the public an opportunity to compare the methods of illuminating. The light furnished by the Siemens Company was quite satisfactory, and at the same time their process of combustion assisted materially in keeping the room ventilated.

Outside the buildings and fixed with brackets to the side of the structure there was a cordon of arc lights of the Brush Electric Company of Cleveland. The grounds about the buildings and annex, were lighted in like manner by the Thomson-Houston Company. To accommodate visitors arriving and departing by the Powelton avenue station of the Pennsylvania railroad, located three squares from the exhibition, the Van De Poele Company of Chicago run a series of arc lights along the sidewalks the entire distance. In addition to this exterior lighting, for practical uses, the brilliancy of the scene was still further enhanced by the display of lights from the towers by the companies named, and also by a large collection of Edison white and colored incandescent lamps, forming a star of dazzling beauty, and seen at a long distance from its location on the southeast tower.

UNITED STATES ELECTRICAL CONFERENCE.

Prominent among the list of scientific associations that visited the exhibition was the United States Electrical Conference. In May, 1884, an act of Congress was approved by the President, authorizing the appointment of a scientific Commission "which may in the name of the United States Government conduct a national conference of electricians in Philadelphia in the autumn of 1884." By virtue of this bill the "United States Electrical Commission" was created for the purposes set forth. Professors Henry A. Rowland, George F.

Barker, Simon Newcomb, C. F. Brackett, J. Willard Gibbs, John Trowbridge, F. C. Van Dyck, Charles A. Young, M. B. Snyder, E. diven J. Houston, Dr. W. H. Wahl and Mr. R. A. Fisk, comprising the board, issued invitations to a large number of scientific gentlemen, both foreign and American, to assemble in conference. There was a large number of acceptances, and the meetings were held in September, first in the lecture hall of the exhibition, and afterward at the building of the Franklin Institute. A perusal of the report of papers read and the discussions consequent thereon confirms the statement of the preamble to the bill creating the Commission that "The International Electrical Exhibition offers a rare and fitting opportunity for such an official assemblage of electricians." The members of this Commission manifested a cordial desire for the success of the exhibition, and the endeavor to gather from the display the fruits of scientific tests and examinations.

COMMITTEE ON MEASUREMENTS AND TESTS.

In addition to their work in the conference, Professors Brackett, Young, Van Dyke, Trowbridge, Anthony and others, spent days of valuable time rendering important voluntary assistance as members of the Committee on Measurements and Tests. The last-named committee was appointed by the Board of Managers of the Franklin Institute, and was an independent body working without the direction or control of the Committee on Exhibitions. The Chairman, Prof. M. B. Snyder, of the Central High School of Philadelphia, succeeded in obtaining the services of a number of the most prominent scientific men in the country to act as examiners in this and other work connected with the exhibition. The results of examinations by this board of examiners will be the subject of special reports to the Institute, and are now being published as fast as completed.

For the purpose of affording needed facilities for investigation, especially in delicate tests and measurements, a frame structure was erected upon a lot of ground on Lancaster avenue, west of Thirty-

EXHIBIT OF THE THOMSON-HOUSTON ELECTRIC COMPANY.

third street loaned by the Pennsylvania railroad. Within this building a photometric room was constructed, and piers built for the installation of instruments of precision. Upon the grounds adjacent, a large number of telegraph poles were erected, and wires placed thereon, with frequent loops to obtain length of circuit and to form a rheostat. In this latter service material aid was rendered by the efficient Chief of the Electrical Department of the City of Philadelphia, David R. Walker. The committee are indebted to Mr. Walker for many facilities and services afforded by his department.

SOME OF THE EXHIBITS.

The official catalogue, furnished with commendable promptness by Burk & McFetridge, gives a full list of exhibits and renders further details unnecessary. There are, however, some features of the display that deserve special mention, on account of their extent and character. The Edison exhibit, representing the six companies of the combination, occupied several large spaces, and the great variety of instruments, appliances and machines were arranged with attractiveness. The incandescent system was shown completely organized as from a central lighting station. The extreme beauty of their lamp clusters and electroliers was illustrated in their own space, also in the offices of the exhibition, lighted by this Company, and in several well-furnished rooms and private exhibits. A prominent feature, and one that attracted a great deal of attention, was a pyramid thirty feet high, and six feet at base, containing twelve hundred incandescent lamps. At regular hours it was illumined, and was the centre of great interest to visitors. Their large incandescent dynamo invited especial attention.

The United States Company exhibited both arc and incandescent lighting. It occupied a large amount of space, and the display was exceedingly creditable in materials and in artistic arrangement. Several of the electroliers were of remarkable beauty.

No Company presented a more systematic display of electric lighting machines and accessories than the Thomson-Houston Company,

and it was particularly valuable from an educational point of view. The exhibit had been carefully set up in Lynn before it was brought to Philadelphia, and throughout gave evidence of the conception of a perfect organiser. Some of the instruments, with mechanism dissected, illustrating the principles involved in working their machinery, and the large solenoid, showing curious magnetic effects were the source of continued study especially by amateurs. The thoughtful courtesy of Mr. Peck in working the projecting lantern for the fountain, places the committee under obligations to him.

The Brush exhibit is well described in the Catalogue. The furnished interiors, drawing-room, bed-room, office and mill-room were well arranged to illustrate interior illumination, and were lighted by the Swan incandescent lamps run by Brush low tension dynamos. The storage or secondary batteries shown in operation attracted universal attention.

The display made by Edward Weston, Newark, N. J., was a notable one in extent, and remarkable for the good taste displayed in conjunction with much apparatus of a highly scientific character.

Show-cases filled with exquisite electro-plates of natural objects, as ferns, leaves, flowers and golden rod, and with perfect reproduction of the greatest triumphs of Japanese and classic art-metal-work, gave a handsome and perfect illustration of electro metallurgy.

The display of Mr. Weston also embraced machines and apparatus used in the manufacture of incandescent lamps. The visitor was shown the method of forming the carbon from the gun cotton to the finished filament of tamidine ready for the treatment of a skilled workwoman. The exhausting processes, by means of the Geissler and Sprengel pumps, were also shown. The exhibits were placed under a canopied area which contained a rare display of the scientific instruments required in actual practice. These instruments were for the most part made by or under the personal direction of Mr. Weston, and evidenced most thorough and careful workmanship. The study of their mechanism afforded much satisfaction to electricians.

Great admiration was evinced by visitors for a mimic waterfall for

which the water was pumped by electrical motors. The ingenious arrangement of cork bark to simulate rocks, and the exquisite taste displayed in the arrangement of flowers, was due to Mr. Alex. P. Wright in charge of this exhibit. His constant affability as well as that of his assistants added much to the pleasure of many of the visitors.

Not only on account of his world-wide reputation, but also for the evident interest he manifested in the exhibition, the display of the productions of Thos. A. Edison was a prominent feature. Mr. Edison gave personal supervision to the arrangement of details, and the description in the catalogue affords a study of electrical matters that seems marvelous. The "speaking phonograph," "musical telephone," "motophone," "chemical recording telegraph," "electric motograph," are but a few of the wonderful and complex machines spread out for curious eyes to examine.

In addition to the larger display of the electric light companies, the Van De Poele, Ball, Bernstein, Excelsior, McTighe, Union Switch and Signal Co. and others, gave handsome illustrations of their systems.

The most prominent exhibit by telephone companies was made by the American Bell Co. conjointly with the Western Electric Co. A telephone exchange system was established connecting some twenty-five exhibitors with the offices of the Exhibition, and the subscribers of the Philadelphia Exchange. The Exhibit was an interesting display of a large variety of telephones from the first invention to the more recent patents. Somewhat less conspicuous than others, but exceedingly valuable and suggestive, was the contribution of Professor Amos E. Dolbear, of Boston. His original magneto-telephone and his system of electrostatic telephones, transmitters and receivers have a valuable reputation for work and ingenuity well known to experts, and their effect in operation was continually tested by electricians.

The private exhibits of Prof. Asa Gray, occupying a large space in the main hall, was a very important one, illustrating the wonderful inventions of a man known throughout the country as a pioneer in electrical work. The Professor manifested great interest in the exhibi-

tion by the care and labor bestowed in collecting and forwarding this attractive showing of the life-work of a master. A leading feature of the display was the Harmonic system of telegraphy. By a most unfortunate accident all mention of Gray's exhibit is omitted in the catalogue.

By a singular coincidence, on the side of the main hall directly opposite to the exhibit of Mr. Gray, of his Multiplex Harmonic method, was the most recent advances of Mr. Delany in Synchronous Multiplex Telegraphy. This was an interesting exhibit from the novel character of the results obtained. By means of this system, as many as seventy-two separate and distinct telegraphic messages can be sent over a single telegraphic wire, either all in the same direction, or any part of the entire number in one direction, and the remainder in the opposite direction. This exhibit attracted the liveliest attention both from practical electricians and from scientific men. From the former on account of the great advance in the actual operations of telegraphy effected by the use of the system, and from the latter because Mr. Delany has obtained in the use of his system a synchronism more absolute than ever before thought possible.

FOREIGN EXHIBITORS.

The large majority of foreign exhibitors availed themselves of the advantages to be derived from the agency of American firms. The Electrical Supply Co., of New York, Theodore Mace, Agent, and Jas. W. Queen & Co., Philadelphia, in addition to their own manufactures and importations, represented about forty different makers. Some of the consignments of the latter firm passed the Custom House at so late a period that there was but little time for proper examination. As the invoices covered goods of great value, and represented the more recent inventions of prominent firms, it has been deemed advisable for general information to append a brief description of some of the most important apparatus and instruments.

The display made by James W. Queen & Co. was of great value to the

Exhibition, especially from a scientific and educational point of view, as they had with promptness and energy collected and arranged one of the largest and most complete collections of apparatus for electrical measurements and educational purposes ever exhibited in this country, representing many of the most celebrated makers of physical instruments in Europe. The efforts of Queen & Co. to induce foreigners to exhibit met with an amount of success which was of great importance to the International character of the Exhibition. By means of these efforts the Exhibition was fortunate in securing complete exhibits of the well-known apparatus of Carpentier, Breguet, Edelmann, Hartmann, Verdin and the Société Génevoise.

The Queen & Co. exhibits included beside a full line of standard electrical test instruments, apparatus for physical and physiological research and general demonstration.

From the celebrated house of Ruhmkorff (Carpentier, successor) they showed an immense Ruhmkorff Coil, which gave a spark of about twenty inches; a new Thomson galvanometer, and various electrometers, magnetometers, volt- and ampèremeters, etc., of fine workmanship.

The house of Breguet sent several consignments of the famous Gramme machines, Serrin Regulators, Planté Secondary batteries. These attracted much attention, and formed a valuable addition to the display.

Queen & Co. also exhibited Gerard's Dynamo Machines, which were here for the first time exhibited in this country. Among those shown were some small dynamos with accessories for class demonstration. These machines, with the dynamo machines of De Meritens and Fein, made a full exhibit of this class of apparatus. The dynamo machines of C. Fein, were mounted on tables, and were designed for educational purposes.

In this connection an important exhibit was made of the famous Jablochkoff candles which were run by one of the large alternating current machines of the well-known house of De Meritens. The machines are largely used by the French and English governments in

their lighthouses. The same firm sent over one of these large machines expressly adapted for use with Jablochkoff candles, and was used to furnish the light for Queen & Co.'s space during the entire exhibit.

Another important feature was the collection of fine test apparatus from the well-known German houses of Edelmann and Hartmann. Their instruments possess many novel features, and are peculiarly well adapted for accurate work. They have been, heretofore, comparatively little used in this country, and were objects of interest to scientific men on account of their accuracy of construction and reasonable cost. The instruments of special value in the collection from Hartmann were the Kohlrausch galvanometers, reading telescopes and resistance coils. The last named were adjusted to the new Ohm, which gave them a peculiar interest.

The large Edelmann absolute galvanometer, and the large Wiedemann galvanometer for accurate measurements, are very fine instruments, as are also the astatic galvanometers and the quadrant electrometers. Several of these were used in the Test-house.

Of English electrical test instruments, Queen & Co. exhibited a number of resistance coils and Sir William Thomson's reflecting galvanometers, from the celebrated house of Elliott Bros.; also the instruments of Ayrton & Perry, and Paterson & Cooper. They also had a collection of apparatus from C. J. Simmons (for many years with Elliott Bros.), whose test instruments including resistance coils and Wheatstone bridges were very good, and useful for educational purposes. They also exhibited some of Prof. S. P. Thompson's electromotors and apparatus from the well-known house of Siemens Bros. & Co.

Of Physiological apparatus the varied collection from the house of Ch. Verdin, of Paris, was quite complete. These were much admired. The Cambridge Scientific Co. also sent a large and complete exhibit of their well-known apparatus.

The beautiful collection of Instruments of Precision, such as divided bars, micrometers, spectrometers and cathetometers from the Société Génevoise, were of special interest to our prominent physicists. The instruments of this house are very accurate and of beautiful construc-

tion and finish, and recent tests have developed fresh proofs of their precision.

There was also exhibited a fine collection of medical electrical apparatus from G. Dupré, and the electrical apparatus of Cloris Baudet, as well as the speed-counters and recorders of Deschien.

Queen & Co. also had a large number of Holtz machines, both of their own special importation, made for them abroad, and also their new American form, manufactured by themselves. This firm was the first to introduce the Toepler-Holtz machine in this country. Their collection was very complete, and as the machines were constantly in operation, they were features of the Exhibition.

Their display of Geissler' and Crookes' tubes was especially fine. They erected in the main building a dark room specially for the exhibition of these tubes, for apparatus for projection, and for other valuable optical apparatus from the famous house of Duboscq. They also showed a great variety of chemical apparatus, incandescent lamps, apparatus for sugar chemists, crystal models, and physical apparatus generally.

The description of Queen's exhibit in the catalogue is well worthy examination. Besides the electrical apparatus there was a large showing of accessories and optical instruments. Among the former was a fine mercury pump for exhausting the globes of electrical lamps under high vacua. This instrument was interesting as being a contribution from Dr. Geissler, of Bonn, and from his workshop. Drs. Steeg and Reuter sent over a collection of great value consisting of sections of crystals and polariscopic and optical instruments.

At the series of lectures which were given during the Exhibition by eminent scientific men, the instruments used were mainly obtained from the exhibit of Queen & Co., who in the most cordial manner offered the free loan of all the apparatus necessary for illustration. Especially was this the case at the lecture of Prof. Forbes on "Dynamo Machines;" and at that of Mr. A. E. Outerbridge on "Radiant Matter," where a very large and complete set of Geissler and Crookes tubes was furnished and exhibited, and the lectures of Prof. Houston to the

school children. At the lecture on the "Wave Theory of Light," given at the Academy of Music, by Sir William Thomson, under the auspices of the Institute, Queen & Co. supplied the lantern and a number of other instruments, and also gave their personal assistance, thus aiding materially in the success of the lecture.

A number of very fine Galvanometers and Reading Telescopes from Hartmann and Edelmann were loaned to the committees and were in use at the Test-house during all the tests.

The services of Queen & Co. to the Exhibition Committee in the loan of apparatus was rendered still more valuable by their detail of skilled assistants to place the instruments in working order and to superintend their operation when in use for lectures. To deprive themselves for considerable periods of time of the services of these gentlemen no doubt caused the firm considerable inconvenience, and the kindness is appreciated by the Institute.

In a report giving a brief glance at the more prominent points of interest it is of course impossible to mention many entries of goods that were equally attractive. Hanson, Van Winkle & Co., Newark, N. J., electro-plating; the printing press of N. Y. Electrical World, run by electric motor; Bidwell's railway; the Union Switch and Signal Co.'s extensive plant and ingenious devices for railroading; the electrotypes of Messrs. Ready, of the British Museum, kindly loaned by the American Numismatic and Archæological Society of New York; the Clay Commercial Telephone, with its system of exchange, all suggest a great variety of other interesting matter fully described in the catalogue.

Among the foreign visitors to the Exhibition were many scientific men of world-wide reputation. Prominent in the lists are recorded Sir Wm. Thomson, Lord Rayleigh, Prof. Sylvanus P. Thompson, W. H. Preece, Prof. George Forbes, Lieuts. F. R. De Wolski, and Chisholm Batten, official representatives of Great Britain; Prof. Tchisuke Fujoka, Tokio, Japan; F. N. Gisborne, Government Electrician for Canada; Señor Enrique A. Mexia, official representative of Mexico,

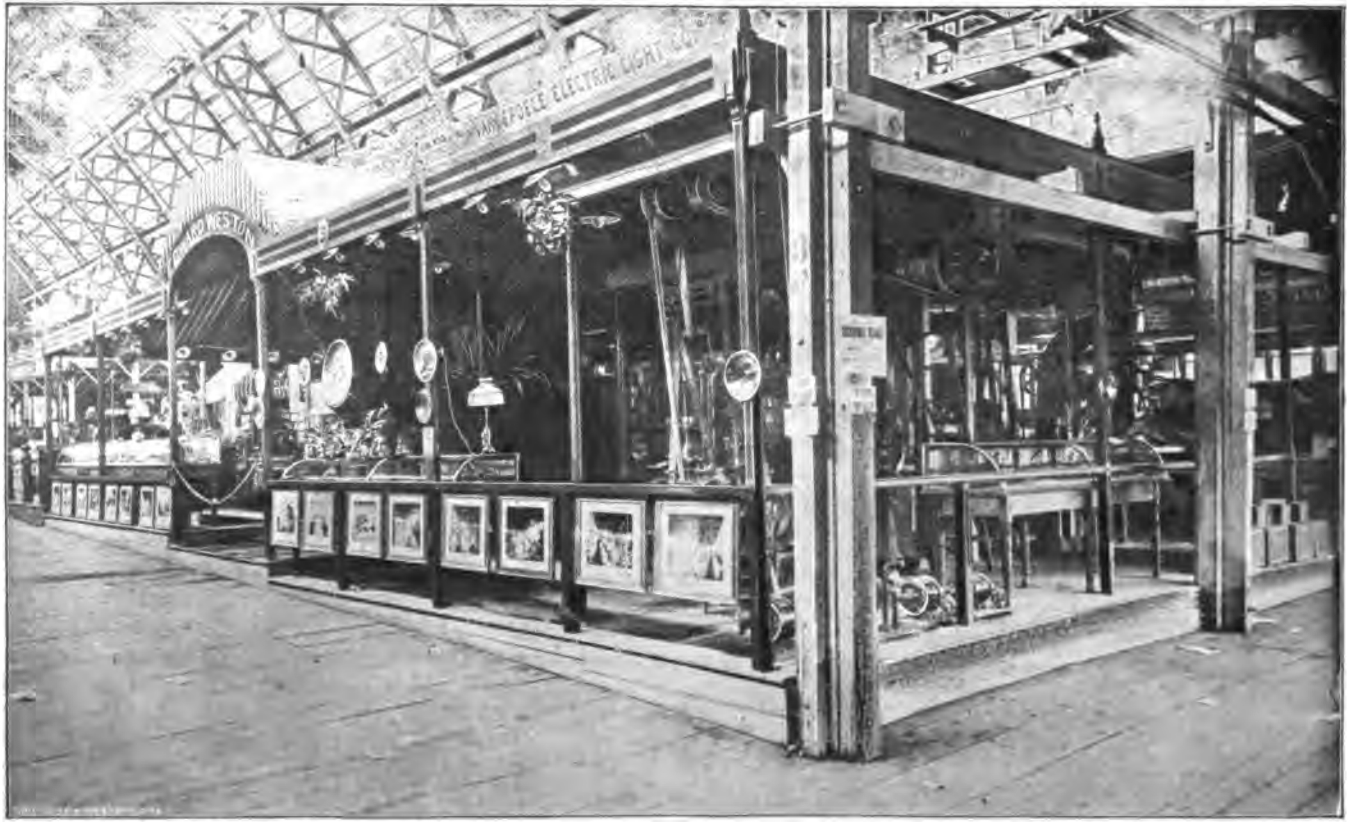


EXHIBIT OF EDWARD WESTON.

and others whose names appear among the members of the Electrical Conference.

The report of the Treasurer shows the Exhibition to have been a financial success. The entire expense of erection of buildings, the cost of shafting, steam piping and general preparations, as well as the running expenses, were promptly met and a balance of a few thousand dollars left in the treasury. This was accomplished without Government aid, or the use of public moneys.

As has already been stated, there was no fire or alarm during the entire period. Nor was there a panic at any time in the immense crowds of visitors, and an entire freedom from accidents and loss of life or injury to employés or visitors. When it is remembered that the buildings, temporary in character and constructed of inflammable materials, were filled with machines that ignorance or carelessness might turn into engines of destruction, the care of Divine Providence is manifested. To Him shall we render our thanks.

Respectfully submitted,

CHARLES H. BANES, *Chairman.*

APPENDIX.

COMMITTEE ON EXHIBITIONS.

CHARLES H. BANES, *Chairman.*

William P. Tatham,
Charles Bullock,
Frederick Graff,
Joseph E. Mitchell,
Samuel Sartain,
Washington Jones,
A. E. Outerbridge, Jr.,
William D. Marks,
Cyrus Chambers, Jr.,
Addison B. Burk,
E. Alex. Scott,
G. Morgan Eldridge,
Lewis S. Ware,
Chas. S. Shain,
C. Wesley Lyons,
Edward Longstreth,
Chas. E. Ronaldson,
Henry C. Davis,
Luther L. Cheney,
Thomas Hockley,
W. W. Griscom,
Wm. V. McKean,
William Sellers,
Frederick Fraley,
John J. Weaver,
Joseph M. Wilson,
Coleman Sellers,
Isaac Norris, Jr.,
Theodore D. Rand,
J. Vaughan Merrick,
Henry R. Heyl,
William B. Cooper,
Hugo Bilgram,
Charles Faser,
John Baird,
Chas. M. Cresson,
Horace W. Sellers,
David Brooks,
Henry Morton,
W. J. Phillips,
H. H. Levette,
J. H. Linville,
John B. De Motte,
Edwin J. Houston,
Wm. H. Thorne,
Persifor Frazer,
Enoch Lewis,
William Helme,
C. Chabot,
Pliny E. Chase,
Hector Orr,
Robert E. Rogers,
Jules Viennot,
Luigi D'Auria,
S. R. Marshall,
M. B. Snyder,
Raphael Estrada,
N. H. Edgerton,
Coleman Sellers, Jr.,
Louis H. Spellier,
S. Lloyd Wiegand,
Wm. Barnet Le Van,
Murray Bacon,
Carl Hering.

WILLIAM H. WAHL, *Secretary.*

Special Committees.

Superintendent.—William D. Marks.
Electrician.—Edwin J. Houston.
On Finance.—Frederick Fraley, *Chairman.*
On Space.—Charles Bullock, *Chairman.*
On Transportation.—Enoch Lewis, *Chairman.*
On Classification.—Pliny E. Chase, *Chairman.*
On Bibliography.—Isaac Norris, Jr., *Chairman.*
On Buildings and Machinery.—Frederick Graff, *Chairman.*
On Rules and Regulations.—Coleman Sellers, *Chairman.*
On Custom House Regulations.—Charles Bullock, *Chairman.*
On Correspondence and Publication.—William H. Wahl, *Chairman.*
On Historical Electrical Apparatus.—Edwin J. Houston, *Chairman.*
On Electrical Installation.—Edwin J. Houston, *Chairman.*
On Admissions.—Samuel Sartain.
On Board of Examiners.—M. B. Snyder.

LIST OF GUARANTORS INTERNATIONAL ELECTRICAL EXHIBITION.

A. J. Drexel	$1,000
Geo. W. Childs	1,000
W. P. Tatham	1,000
Fairman Rogers	1,000
Henry C. Gibson	1,000
John Baird	1,000
J. V. Merrick	1,000
B. H. Bartol	1,000
Alex. Biddle	1,000
Henry Bower	1,000
Wm. Sellers & Co	1,000
Chas. H. Banes	1,000
A. Whitney & Sons	1,000
Henry Disston & Sons	1,000
Burnham, Parry, Williams & Co	1,000
H. Belfield & Co.	1,000
James Moore	1,000
Hoopes & Townsend	1,000
I. P. Morris Co	1,000
John Wiler	1,000
John Wanamaker	1,000
Washington Jones	1,000
P. A. B. Weidener	1,000
Brush Electric Light Co. of Philadelphia	1,000
Morris Wheeler & Co	500
W. D. Rogers, Son & Co	500
F. Gutekunst	500
Hughes & Patterson	500
Henry Howson	500
G. B. Roberts	500
Chambers Bros. & Co	500
Allan, Wood & Co	500
S. Lloyd Wiegand	500
Thos. Hockley	500
John G. Baker	500
G. W. Fiss	500
Percival Roberts	500
Wm. M. Singerly	500
Wm. D. Marks	500
Wm. Helme	300
Erben, Search & Co	250
C. H. Hutchinson	250
H. Bottomley	250
Chas. Platt	250
Geo. V. Cresson	250
Chas. Bullock	250
J. E. Mitchell	250
Frederick Graff	250
E. F. Houghton & Co	250
Walter Wood	200
Frederick Fraley	100
Lewis S. Ware	100
William H. Wahl	100
James Rowland	100
Theo. R. Wolf	100
Alfred Mellor	100
Henry N. Rittenhouse	100
Edward Rowland	100

Alexander Bros	100
Persifor Frazer	100
J. R. Claghorn	100
E. and F. N. Spon	100
Frederick Shober	100
Edward Samuel	100
Isaac Norris, Jr	100
Robert Frazer	100
Theodore D. Rand	100
A. E. Outerbridge, Jr	100
Jas W. Queen & Co	100
H. B. Bartol	100
Smith, Kline & Co	100
Aschenbach & Miller	100
Charles Norris	100
Samuel Sartain	100
Centennial National Bank	50
John S. Haines	50
John M. Maris & Co	50
Keasbey & Mattison	50
J. J. Allen's Sons	50
A. Hamilton Patterson	50
M. Buechler	50
Louis E. Levy	50
N. Penrose Allen	25
Wm. H. Thorne	25
F. Foell	25
Harry Rowland	25
A. R. Raymond	25
Dueding Bros. & Co	25
Chas. J. Shain	25

and sundry amounts from the following named persons: Clem & Morse, Milan Bentley, Parker D. Pierce, Harry S. Gross, M. D., Dr. M. F. Grove's Sons, James Rossiter, Geo. S. Wright, H. J. Peters, Wm. Knighton, Wm. H. Beadling, P. C. Broodwell, Christ. Petzelt, C. C. Hughes, John E. Grove, J. R. Landis, Bernhard A. Hertsch, Alexander Wilson, J. F. Hopkinson, Jr., S. Douglass, F. H. Bassett, J. W. Guerdrum, W. P. Keffer.

JOINT RESOLUTION OF CONGRESS AND CIRCULAR OF THE TREASURY DEPARTMENT OF THE UNITED STATES.

TREASURY DEPARTMENT,
Washington, D. C., November 14, 1883.

TO COLLECTORS OF CUSTOMS AND OTHERS:

The following Joint Resolution, approved February 26, 1883, is published for the information and guidance of Customs Officers:

"WHEREAS, the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, proposes to hold an exhibition of electrical apparatus, machinery, tools and implements, and other articles used in scientific and mechanical and manufacturing business and investigations; and

WHEREAS, It is deemed desirable to promote the success of such an exhibition by all reasonable encouragement, in order that it may be made useful to the promotion of knowledge; therefore be it

"*Resolved by the Senate and House of Representatives of the United States of America in Congress assembled*, That all articles which shall be imported for the sole purpose of exhibition at the Exhibition to be held by the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, in the city of Philadelphia in the year eighteen hundred and eighty-three or eighteen hundred and eighty-four, shall be admitted without payment of duty or customs fees or charges, under such regulations as the Secretary of the Treasury shall prescribe:

Provided, That all such articles as shall be sold in the United States or withdrawn for consumption therein at any time after such importation. shall be subject to the duties, if any, imposed on like articles by the revenue laws in force at the date of importation; *And provided further*, That in case any article imported under the provisions of this Joint Resolution shall be withdrawn from [for] consumption, or shall be sold without payment of duty as required by law, all the penalties prescribed by the revenue laws shall be applied and enforced against such articles and against the persons who may be guilty of such withdrawal or sales."

In pursuance of this Resolution, the following regulations are hereby prescribed:

Invoices will be required, which shall recite the fact that the goods embraced therein are intended for this Exhibition. Each shipper will be required to make such invoice in triplicate, giving a description of his goods, their value, and the marks and numbers thereon; but any number of such invoices may embraced in one declaration by the agent, such declaration to be taken before a Consular Officer of the United States and certified in the usual manner. One copy of the invoice will be sent to the Collector of Customs at the port of first arrival, one copy to the Collector of Customs at Philadelphia, and one copy to the consignee or agent of the shipper.

Articles intended for this Exhibition and arriving at the ports of Boston, New York, Baltimore, San Francisco, or New Orleans, or any port on the Canadian frontier at which goods may be shipped for immediate transportation under the Act of June 10, 1880, entitled "An act to amend the statutes in relation to immediate transportation of dutiable goods, and for other purposes" (S. S., 4582), may be shipped by bonded common carriers from the port of first arrival to Philadelphia.

On the arrival of such goods at Philadelphia, either direct or *via* either of the ports named, due notice of such arrival will be given to the Collector by the consignee, whereupon the Collector will take possession of the same. Entry for warehouse, in the usual manner, will be permitted, and the usual bond taken to secure the duties, and, after the bulding shall have been duly bonded, the goods will be stored in the Exhibition building.

Upon completion of the warehouse entry and storage of the goods in the Exhibition building, the packages will be opened and due examination and appraisement of the contents, with proper allowance for damages sustained on the voyage of importation, if any, will be made by the appraiser at such Exhibition building, which shall, for that purpose, be regarded as a public store. After the appraisement shall have been completed, the entry will be liuuidated as usual, and proper record made of the same.

To identify the articles, a ticket will be pasted on each article, giving the name of the shipper stated in the invoice and the number of the warehouse entry. A storekeeper will be stationed at the Exhibition building, at the expense of the Exhibition, who will keep a register of the goods received in a debit and credit account, checking against the receipts the deliveries as they may be made. The goods may be withdrawn for exportation at any time within three years from the date of importation without payment of duties or customs fees or charges. On withdrawal for consumption, however, the usual fees accrue. If not withdrawn for consumption or exportation within that time, they become liable to sale to realize the duties. On sale of any of the goods for consumption in the United States, withdrawal entry will be permitted on payment of duties at the rate in force at the dates of importation of the several articles respectively. On such withdrawal for consumption, after one year from date of original importation, an additional duty of 10 per cent. on the duties originally assessed will be exacted.

Such of the instruments of precision as may require verification and an adjustment for adaptation to the scientific purposes of the Exhibition in

advance of its opening, may be delivered to the Franklin Institute for such preliminary adaptation, upon receipts signed by the President or Vice-President of the Institute.

The Circular of March 22, 1883, No. 27, upon the same subject, is hereby repealed.

CHAS. J. FOLGER.
Secretary.

RULES AND REGULATIONS.

1. The building at Thirty-Second street and Lancaster avenue, will be opened for the reception of the articles and goods intended for Exhibition on Monday, August 11th, and remain open for that purpose until Saturday, August 30th. On Tuesday, September 2d, the Exhibition will be formally opened to the public at 12 o'clock M., and continue open daily (Sunday excepted) from 10 A. M. to 10 P. M., until Saturday, October 11th.

2. Each exhibitor will be required to pay an entrance fee of $5, for which he will receive one season ticket of admission not transferable and issued to any one of the members of a firm or corporation that may be exhibitors; additional tickets for other members of a firm or the executive officers of corporations being procurable at the same rate for each person. Tickets of admission for the attendants absolutely necessary for the care and operation of the exhibits can be procured free of charge subject to the regulation of the Committee in charge of tickets, and these tickets are to be forfeited if wrongfully used.

The charge for space occupied by exhibits, either on the floor or under the ground, or suspended above the aisles, or on the walls (to be paid upon the receipt of permit) will be as follows:

	All spaces under 10 square feet	$2 00
	From 10 to 100 square feet	20 cents per square foot.
Rates per Square Foot.	100 square feet @ 20 cents	$20 00
	200 square feet @ 17½ cents	35 00
	300 square feet @ 15½ cents	46 50
	400 square feet @ 14 cents	56 00
	500 square feet @ 13 cents	65 00
	600 square feet @ 12¼ cents	73 50
	700 square feet @ 11 4/7 cents	81 00
	800 square feet @ 11 cents	88 00
	900 square feet @ 10½ cents	94 50
	1,000 square feet @ 10 cents	100 00

All spaces measuring over 1,000 square feet...10 cents per square foot.

The rate per square foot for any fractional excess of space over any even hundred in the above table will be the rate of such hundred diminished by a due proportion of the difference between that rate and the rate of the next hundred.

3. All applications for space must be made before August 30th, on printed blank forms, to be furnished by the Committee; and they will be con-

sidered and the space allotted to applicants in the order of their reception; and space allotted to exhibitors, but not occupied by August 30th, may be assigned to other exhibitors. Whenever the articles will admit, exhibitors are requested to display them in glass cases.

4. All articles delivered at the building shall be reported to the Committee, who will direct their location and assign them the proper space. Any article shipped to the Exhibition by rail or otherwise, must have freight and charges prepaid, and invoice and Bill of Lading mailed to "Committee on Exhibition, Franklin Institute, Philadelphia, U. S. A."

5. Exhibitors or their agents will be furnished by the entry clerk with duplicate cards, upon which must be placed a description of each article entered for exhibition; these will be countersigned on the receipt of the articles into the Exhibition. One of these cards shall be conspicuously attached to the article which it describes, and the other must be retained by the exhibitor, and be presented as his order for the delivery of the article specified, at the close of the Exhibition.

6. The Committee reserve the right to exclude from the building and premises all articles of a dangerous or offensive or otherwise objectionable character.

7. No article can be removed from the building during the time of the Exhibition, unless by consent of the Committee.

8. A police force will be in attendance upon the premises during the Exhibition and watchmen at night; but all articles on exhibition will be at the risk of the owner.

9. Power will be furnished to drive machines at the rate of three cents per horse-power per hour, the power to be rated at sixty square feet per minute of belt if the belt is single, and forty square feet per minute if the belt is double. The tension on belt to be subject to the judgment of the engineer of the Exhibition in charge, whose decision is final. If machines are driven direct from engines furnished by the exhibitors, the steam used will be rated by indicator, and charged at the same rate per horse-power. Full credit will be given for power for creating light ordered by the General Superintendent.

10. Signs will not be allowed of greater size than 500 square inches, nor shall such signs be elevated above the exhibits. The distribution of circulars, cards or samples about the building will not be permitted; exhibitors can distribute such things only from their own stand.

11. The arrangement and distribution of the electric conductors in all parts of the building shall be wholly under the direction of the Electrician in charge, who will decide on the position and determine the character of the insulation. under the rules laid down by the Committee.

12. No Awards or Premiums are offered by the Institute, but in place thereof a report to the Institute will be prepared by a Board of Examiners, which report will be as full as the time and opportunity will permit. Exhibitors are requested to give at the time of the opening of the Exhibition detailed descriptions of their exhibits addressed to the Board of Examiners, describing the merits of each exhibit as understood by the Exhibitor, such matter, at the discretion of the Examiners, to be used in their report. If, however, any of the exhibitors desire expert examination or competitive

tests of their displays, such tests will be conducted by the Institute to the extent practicable in the time, provided the cost of the materials and instruments used be borne by the exhibitors desiring the test. The Special Committees to whom these tests will be referred will be appointed by the Board of Managers of the Institute, subject to the approval of a majority of those asking for the test if it is competitive. The original copy of all reports shall remain the property of the Institute, which shall have the first right of publication.

The Institute reserves the right to enter into such other scientific work touching the Exhibition (not requested by the exhibitors) as in its judgment may tend to the advancement of science.

The Examiners shall be appointed by the Board of Managers and shall be men of acknowledged integrity, skill, and experience in the class of goods assigned to them, and no Examiner shall serve on any class in which he may be an exhibitor or be otherwise directly interested. The mornings of each day until fifteen minutes before the time of opening the Exhibition, shall be appropriated to the Examiners who shall be attended only by such persons as they may invite to be present.

13. Exhibitors are required to attach to their exhibit a printed description in English of the use and operation of the object exhibited, for public information, if at any time the exhibit should be left without attendants who can explain it.

SYNOPSIS OF CLASSIFICATION.

SECTION I.—*Production of Electricity.*

Class I. Apparatus for Electricity of High Electromotive Force.
Class II. Voltaic Electric Apparatus.
Class III. Thermo-Electric Apparatus.
Class IV. Magneto-Electric Apparatus.
Class V. Dynamo-Electric Apparatus.
Class VI. Mechanical Motors — Steam, Gas, Water, Heat and Wind Engines.

SECTION II.—*Electric Conductors.*

Class I. Telegraph Wires.
Class II. Telephone Wires and Cables.
Class III. Electric Light Circuits.
Class IV. Underground Conduits for Electric Conductors.
Class V. Sub-Marine Cables.
Class VI. Insulating Materials for Conductors.
Class VII. Electrical Joints and Connections.

SECTION III.—*Measurements.*

Class I. Measurements of Dimensions.
Class II. Measurements of Speed, Force and Energy.
Class III. Electrical Measurements.
Class IV. Photometric Measurements.

SECTION IV.—A.—*Applications of Electricity.*

(Apparatus requiring Electric Currents of comparatively Low Power.)

Class I. Electric Telegraphs.
Class II. Telephones, Microphones, Photophones and Radiaphones.
Class III. Fire and Burglar Alarms.
Class IV. Annunciators.
Class V. Electric Clocks and Time Telegraphs.
Class VI. Electric Registering Apparatus.
Class VII. Electric Signal Apparatus.
Class VIII. Electro-Medical.
Class IX. Applications of Electricity to Dentistry.
Class X. Applications of Electricity to Warfare.
Class XI. Applications of Electricity to Mining and Blasting.
Class XII. Applications of Electricity to Spinning and Weaving.
Class XIII. Electrical Traps and Snares.
Class XIV. Applications of Electricity to Pneumatic Apparatus.
Class XV. Applications of Electricity to Musical Instruments.
Class XVI. Applications of Electricity to Writing and Printing.
Class XVII. Electrical Toys.
Class XVIII. Electrical Conjuring Apparatus.
Class XIX. Miscellaneous Applications of Small Currents.

SECTION IV.—B.—*Applications of Electricity.*

(Apparatus requiring Electric Currents of comparatively Great Power.)

Class I. Electrical Illumination.
Class II. Electro-Metallurgy.
Class III. Other Applications of Electro-Chemistry.
Class IV. Storage Batteries and Accumulators.
Class V. Electric Motors. Transmission of Power.
Class VI. Electro-Magnetic Brakes.
Class VII. Miscellaneous Applications of Large Currents.

SECTION V.—*Terrestrial Physics.*

Class I. Atmospheric Electricity.
Class II. Terrestrial Magnetism.
Class III. Apparatus used by Governments for Weather Signal Stations.

SECTION VI.—*Historical Apparatus.*

SECTION VII.—*Educational and Bibliographical.*

THE PROPOSED CONFERENCE OF ELECTRICIANS AT PHILADELPHIA.

In order to secure to the fullest extent the unusual advantage arising from the coincidence in the time of holding the proposed International Electrical Exhibition in Philadelphia, and of the meeting of the American Association for the Advancement of Science in the same city, in connection with the anticipated visit of the members of the British Association to this city, the Franklin Institute has appointed a special committee to confer with scientific men as to the best method to be adopted for securing, during the month of September, the assembling at Philadelphia of a Conference of Electricians.

To defray the expenses of such a conference, a bill has been prepared asking for a small appropriation from Congress.

Scientific men interested in this measure are earnestly requested to give it all the aid in their power.

Communications on the subject are respectfully requested by the committee.

M. B. Snyder,
Edwin J. Houston,
Wm. H. Wahl,
Wm. P. Tatham,
Committee.

PUBLIC SCHOOL CIRCULAR.

The Franklin Institute, desirous of manifesting the interest it takes in cultivating a taste for useful knowledge in the Public Schools, and making the benefits of the Electrical Exposition available to the pupils in a more positive degree than can be accomplished by simply visiting the building, has decided to award a number of prizes to the pupils, of the character and upon the conditions set forth below:

1. A prize to be awarded for the best essay presented by the Boys' Grammar School and by the Girls' Grammar School of each section, by each class in the Girls' Normal School, and by each class in the Boys' Central High School.

2. The prize to be awarded to each school and class shall be five dollars and a handsomely engraved certificate, setting forth the distinction

obtained by its holder. The prize will be awarded at a public meeting to be held at the lecture room of the exhibition.

3. The subject of the essay shall be, "What I Saw at the Electrical Exhibitien." The essay must contain an account of some electrical phenomenon, piece of machinery, apparatus or appliance on exhibition. No essay containing simply an exposition of principles, or their application to uses not represented in the exhibition, will be considered as meeting the requirements of the competition.

4. The essay must be written on medium ruled foolscap paper, and must not be less than two nor more than four pages in length. It must have the name of the school and section written at the top of the first page, and be subscribed with a motto at the end. This motto is to be written on the face of a sealed envelope containing the pupil's name, age, section, school and class. The pupil's name must not appear in any form on his or her essay.

5. The points to be considered in deciding upon the merits of the essays are the discrimination exhibited in selecting the object which forms the subject-matter of the essay, and the clearness, neatness and accuracy with which this object, the scientific principles which it involves, or the uses to which it is applied, have been described. The essay need not necessarily be confined to one object. Rhetorical qualities are not to be considered and unimportant grammatical errors are to be diregarded. The essay is intended to be a test of the pupil's observing powers, and his ability to describe accurately, in simple terms, what he has actually seen and examined for himself.

REPORT OF THE LECTURE COMMITTEE TO THE COMMITTEE ON EXHIBITIONS.

COL. CHAS. H. BANES, *Chairman Committee on Exhibitions.*

SIR:—The special committee appointed shortly before the opening of the Exhibition, to arrange a series of lectures in connection with the International Electrical Exhibition, submit herewith their report:

The large assembly room in the annex was set apart for the Committee's use, in which it was decided to hold, on two evenings of each week during the progress of the Exhibition, lectures on topics more or less directly connected with Electricity. The evenings of Tuesday and Thursday were selected as being the most suitable for the purpose. Correspondence was opened with a number of well-known specialists, which resulted in receiving the services of the following gentlemen, who lectured in the order indicated, upon the subjects set opposite to their names:

Date.			Lecturers.	Subject.
Sept.,	Tuesday,	16.	Prof. Geo. Forbes, F.R.S.E., of London......	Dynamo-Electric Machinery.
"	Thursday,	18.	Rossiter W. Raymond, Ph.D., of New York, Sec. Am. Inst. Mining Engineers.	The Divining Rod.
"	Tuesday,	23.	Nathaniel S. Keith, of New York, Sec. Am. Inst. Electrical Engineers....................	Electro-Metallurgy.
"	Thursday,	25.	Prof. Chas. A. Young, of Princeton, N. J...	The Physics of the Sun.
"	Tuesday,	30.	Prof. Harrison Allen, M.D., of Phila.........	Electricity in Medicine
Oct.	Thursday,	2.	Prof. Chas. F. Himes, Ph.D., of Carlisle, Pa.	Actinism.
"	Tuesday,	7.	Prof. Persifor Frazer, D.Sc., of Phila..........	Crystallization.
"	Thursday,	9.	Mr. Alex. E. Outerbridge, Jr......................	Radiant Matter.

The foregoing lectures were held in the Lecture Hall provided therefor in the Annex, and which was provided with a suitable temporary platform and lecture tables. The large apartment was appropriately decorated and was provided with seats for about five hundred persons. Aside from its great height, which made it difficult for a lecturer to be distinctly heard, the room was very well adapted for the Committee's uses. The lectures were all well attended, the room being frequently crowded to its utmost capacity, testifying to the wisdom of the management in deciding to introduce lecture courses as a portion of the educational work of the Exhibition.

All the lectures were more or less fully illustrated, by the use of the projecting lantern, and with apparatus and materials drawn from the Exhibition. The lectures were free to all visitors to the Exhibition.

In addition to the above-named lectures, the Committee were enabled with the co-operation of the President of the Institute, to secure the services of Prof. Sir William Thomson, F.R.S., etc., of the University of Glasgow, who delivered a lecture on "The Wave Theory of Light," at the Academy of Music, on Monday evening, Sept. 29, 1884. Arrangements have been made for the publication of these lectures in the JOURNAL.

The net expense attending the holding of the above-named series of lectures was $507.44, for a detailed statement of which the Committee refer to the account books of the Exhibition.

In addition to the foregoing, arrangements were made, with the cooperation of the Superintendent of Public Sohools and the Board of Public Education, by which the pupils of the public schools of the

City of Philadelphia (of and above the grade of Grammar Schools), were afforded an excellent opportunity of benefiting by the Exhibition. The arrangement referred to, embraced the daily visit of a certain body of the pupils, selected by sections in rotation. This visit to the Exhibition took the place of a school session.

With the object of preparing the visiting pupils to properly observe and understand something of what they would see at the Exhibition, they were permitted first to listen to a lecture having this object in view. This was very elementary in character, and was designed, by means of experimental illustrations and simple explanations thereof, to impress on the minds of the pupils some of the fundamental facts and principles of the science of Electricity.

It is estimated that these lectures were attended by about fifteen thousand scholars of the public schools. Two lectures were delivered daily (Saturdays and Sundays excepted), beginning on the 16th of September and ending on the 9th of October, one being delivered at 9.30 and the other at 10.30 A.M. This duty was most faithfully and satisfactorily performed by Prof. Edwin J. Houston, of the Central High School, with the assistance of Prof. J. B. DeMotte, of DePauw University, Greencastle, Ind.

To still further impress the Exhibition on the minds of the scholars, a plan of competitive prizes was framed, in which each school was permitted to participate. This plan embraced the preparation and submission to a Committee of Judges of a composition by each pupil on "What I Saw at the Electrical Exhibition."

This subject is referred to here as supplementary to the work of this Committee.

The Committee desire, in conclusion, to acknowledge their great obligations to Messrs. James W. Queen & Co., for their liberal assistance in loaning from their superb exhibit of physical apparatus whatever the Committee required, and to express their appreciation of the manner in which Mr. Charles M. Knapp assisted the lecturers.

Appended to this report, are copies of the announcements of the lectures and other matters of reference.

Respectfully submitted by your obedient servants,

William H. Wahl, *Chairman.*
Edwin J. Houston,
M. B. Snyder,
Committee on Lectures.

REPORT OF THE SPECIAL COMMITTEE ON BIBLIOGRAPHY TO THE COMMITTEE ON EXHIBITIONS.

To Col. Chas. H. Banes, *Chairman Committee on Exhibitions.*

Sir:—The Committee on Bibliography was called into existence in pursuance of the following resolution, passed by the Committee on Exhibitions at a meeting held November 3, 1883, and which was approved by the Board of Managers at their stated meeting held November 13, 1883, viz:

Resolved, That a special committee be appointed, to be charged with the preparation of a bibliographical collection relating to the subjects of Electricity and Magnetism, and with its proper exhibition, which collection shall, subsequent to the exhibition, be placed permanently in the library of the Institute as a memorial of the exhibition.

The Committee on Bibliography, as originally appointed under this resolution, consisted of Isaac Norris, M. D. (chairman), Edwin J. Houston, and William H. Wahl, to which, in recognition of valuable services rendered to the committee, the name of John B. De Motte was subsequently added.

To carry out the objects for which it was constituted, the committee caused to be prepared a circular letter, in the English, French and German languages, setting forth their intention of making a collection of the literature of Electricity, and requesting donations of books, pamphlets, and published matter of whatever description, relating to the subject. Such donations the committee promised to suitably display in a special department to be provided therefor in the International Electrical Exhibition, to acknowledge the same in a printed catalogue, giving the titles of the works and the names of the donors, and to place the same, after the close of the exhibition, in the library of the Franklin Institute, where, under the name of the "Memorial Library of the International Electrical Exhibition," it should find a permanent place as a library of reference exclusively.

This circular-letter the committee caused to be sent to publishers, authors and men of science in the United States and in European countries whose addresses were accessible, and had the gratification of receiving favorable responses from a large proportion of those addressed.

Recognizing the impossibility of making a collection worthy of its name and the occasion, without having represented in it the more important older works, now out of print, the committee made an

appeal to t' e friends of the Institute for subscriptions to a fund to be devoted to the purchase of Electrical works of a historical character.

In response to this appeal the committee received gifts of money to the amount of nine hundred and forty-three dollars. (A list of subscribers, with the amounts subscribed by each, is hereunto appended. See Exhibit A.)

EXHIBIT "A."

Gifts of Money Received by the Committee.

Name.	Amounts subscribed.
Thomas Ridgway	$100 00
Mrs. G. Dawson Coleman	100 00
Edwin H. Fitler	100 00
William Sellers	50 00
E. W. Clark & Co	50 00
Henry C. Lea	50 00
William Weightman	50 00
A. J. Drexel	50 00
William F. Jones	50 00
Charles H. Banes	25 00
B. H. Bartol	25 00
C. M. Ghriskey	25 00
C. Schaeffer	25 00
Mr. and Mrs. J. D. Lippincott	25 00
William M. Singerly	25 00
Henry C. Gibson	25 00
G. M. Eldridge	20 00
D. S. Craven	18 00
Washington Jones	10 00
D. N. A. Randolph	10 00
A. B. Couch	10 00
Edward Stern & Co	10 00
Z. C. Howell	10 00
C. H. Borie	10 00
Walter Wood	10 00
E. C. Jayne	10 00
E. O. Thompson	10 00
Dr. James Collins	10 00
John Fauser	5 00
Samuel Allen	5 00
Charles H. Marot	5 00
R. Ledig	5 00
L. R. Buchanan	5 00
D. McAlpine	2 00
E. B. Cooper	1 00
Irwin Lee	1 00
A. H. Patterson	1 00
Total	$943 00

The generous responses to their appeal have enabled the committee to add much valuable material to the "Memorial Library," which they could not have obtained by other means.

Of this amount there has been expended for books and for other needful purposes, by the committee's direction, $669.63, leaving a balance to the committee's credit, on Jan. 1, 1885, of $273.37.

The following summary and analysis will give a sufficiently clear idea of the work accomplished by the committee, viz.:

Whole number of publications received from all sources, and now in the Memorial Library	3,422

They are divided into

Bound volumes	660
Unbound volumes	269
Pamphlets	1,948
Serials	82
Manuscripts	13
Excerpta	4
	2,976

(The apparent discrepancy in totals is explained by the fact that many bound volumes of a single Journal count only as *one* in the analytical table.)

The classification of these publications by nationalities gives the following:

Bound Volumes.

American	353
English	147
French	137
German	22
Dutch	1
	660

Unbound Volumes.

French	94
German	77
American	31
Italian	20
Russian	18
English	9
Dutch	9
Austrian	6
Belgian	4
Swiss	1
	269

EXHIBIT OF THE BRUSH ELECTRIC COMPANY. [An Interior.]

Pamphlets.

English	639
American	422
German	388
Italian	178
French	136
Austrian	66
Belgian	65
Russian	20
Bohemian	14
Dutch	6
Swiss	5
Spanish	4
Danish	4
Portuguese	1
	1,948

Journals.

American	43
French	16
German	8
English	7
Austrian	3
Swiss	2
Italian	1
Spanish	1
Canadian	1
	82

Manuscripts.

English	4
American	3
German	3
French	3
	13

Excerpta.

American	3
English	1
	4

Of the whole number of publications in the committee's collection, there were secured by donations from authors, publishers and others, 2,287, comprising 506 bound volumes, 324 unbound volumes and 1,565 pamphlets, etc.; by purchase with funds subscribed, 1,145, comprising 108 bound volumes, 254 unbound volumes and 783 pamphlets, etc. Total, 2,287 + 1,145 = 3,432.

In accordance with the terms of the circular-letter issued by this committee, the Committee on Exhibitions provided a suitable apartment in the large hall of the depot of the Pennsylvania Railroad Company, in which the collection was shown to advantage. The collection was at all times accessible to visitors, and was constantly consulted.

A subject-matter catalogue, embracing the titles of such works as had been received up to the time of the opening of the exhibition, with the names of the donors, was compiled by Mr. E. Hiltebrant, Librarian of the Institute, under the direction of the committee, and was published as part of the general catalogue of the exhibition. Since the close of the exhibition this work has been completed by Mr. Hiltebrant, by the addition of the large number of works received after September 1, and the enlarged and corrected edition of the catalogue has just been issued under the committee's direction, and forms an octavo volume of nearly 200 pages.

Concerning the character of the collection which the committee has been enabled to make, it may suffice to say that it contains a very satisfactory representation of the current literature of Electricity and Magnetism, copies of many special investigations in the form of authors' reprints, and excerpta from the publications of learned societies, besides a small proportion of the non-current and historical literature.

With the transmittal of this report, the functions of the Committee on Bibliography terminate.

It remains only for the committee to request that you, as the Chairman of the Committee on Exhibitions, will take the steps necessary to fulfill their remaining promise, namely, to place their colleetion in the library of the Franklin Institute as a Memorial Library of the International Electrical Exhibition, to be used exclusively as a library of reference.

Respectfully submitted by your obedient servants,

ISAAC NORRIS, M.D., *Chairman.*
EDWIN J. HOUSTON,
JOHN B. DE MOTTE,
WILLIAM H. WAHL,
Committee on Bibliography.

PHILADELPHIA, January, 1885.

RULES

For the Installation of Electric Apparatus, at the Franklin Institute International Electrical Exhibition, adopted by the Committee on Electrical Installation.

Prefatory.

The following rules and regulations have been adopted for the purpose of securing the highest possible safety both to life and property. It is therefore earnestly requested that all exhibitors will give their hearty co-operation in carrying them into effect.

Rules.

1. All space granted to exhibitors in the International Electrical Exhibition must be occupied in accordance with the rules and regulations of the Committee on Electrical Installation, and all exhibitors must agree to submit to the said rules before such space is allotted to them.

2. No circuits shall be run in the Exhibition Buildings until full plans and particulars thereof are first submitted to the Committee, and approved by them.

3. No changes shall be made in any circuits without the consent of the Committee.

4. Any question pertaining to the installation of electrical apparatus that does not fall within the scope of these rules must be referred to said Committee for decision.

Circuits.

5. All circuits must be insulated and metallic throughout their entire extent; *i. e.*, no ground connections are to be used.

6. The conductors of all main circuits must have such a weight per running foot as will enable them to carry the current employed without heating.

7. When circuits are taken from large to small conductors, and the large conductor carries such a current as would dangerously raise the temperature of the smaller wire, if accidentally diverted through it, an approved automatic safety device must be introduced into the circuit of the smaller conductor, whereby the circuit will be automatically interrupted whenever the current passing through the smaller conductor is in excess of safety. Similar automatic safety devices must be used in all circuits run in the vicinity of electric light and power circuits.

8. All circuit wires for electric light or power currents must be insulated with some approved incombustible material.

9. Circuit wires exposed to moisture must have, in addition to their insulating covering, a coating of some water-proof material.

10. No paraffined or wax-covered wires are to be used in situations or under circumstances where they may be exposed to a high temperature.

11. When the electro-motive force of the current exceeds 300 volts, the different parts of a circuit outside the electro-generator or the apparatus which it energizes, must not approach one another nearer than eight inches.

12. Aerial wires must not have a greater drop than one foot between points of support.

13. All circuits are to be run so as to permit ready and frequent inspection by the committee.

14. When practicable, the positive or outgoing conductor must be clearly marked so as to distinguish it from the negative or return conductor.

15. As far as practicable, continuous wires must be employed. Whenever joints are necessary, they must be made in such a manner as to insure a good and durable contact, and said joints must afterwards be insulated.

16. Wires fastened to walls and ceilings must be rigidly attached to the same by suitable insulating fastenings. In no case will loose loops in the same be permitted.

17. Where circuit wires pass through walls, floors, or ceilings, a special insulating, incombustible tubing must be used to encase the wire.

18. All electric light and power circuits must be tested, as often as the Committee may direct, for accidental grounds, or contacts, and if such are found, the currents shall in no case be permitted in such circuits until such grounds or defects are removed.

19. No circuits shall be placed nnderground within the building.

20. All underground conduits, in use as such, must be placed outside the main building, as may be directed by the Committee, and all circuits connected therewith must be provided with safety devices.

Systems of Electric Lighting.

21. Dynamo-Electric Machines must in all cases be thoroughly insulated from the ground, and be surrounded by a railing so as to prevent the approach of the public nearer than two feet.

22. All Dynamo-Electric Machines must be furnished with means to prevent the dangerous heating of their coils on the extinguishment of part of their lights, and if such means be not automatic in action, a competent person must be in charge of the machine while it is running.

23. Electric arc lamps must be provided with an automatic switch or cut-off, so that the lamp will be automatically cut out from the circuit whenever the current traversing its coils reaches a dangerous limit.

24. All electric arc lamp-frames must be insulated and provided with a hand switch to cut out the light when so desired.

25. All electric arc lights used in the building must be protected by glass globes, furnished with a wire netting outside the globe, to keep the globe in place in case of accidental fracture. Broken or cracked globes must be promptly replaced by sound ones. The bases of the globes must be enclosed so as to prevent the fall of heated particles.

26. A suitable device must be placed on all arc lamps to prevent the fall of the lower carbon, on the failure of its holder.

27. The Committee reserve the right to adopt special preventives in all cases where the safety of the public seems to demand it.

28. The Committe reserve the right to modify these rules in particular cases where it is considered that circumstances warrant such modifications.

29. In all cases requiring prompt action, the exhibitors must be governed by the decision of the Electrician until the matter can be acted upon by the committee.

EDWIN J. HOUSTON, *Chairman*,
HENRY MORTON,
CHARLES M. CRESSON, M. D.,
W. P. TATHAM,
M. B. SNYDER.

SECTIONS OF THE BOARD OF EXAMINERS.

I. Dynamo-Electric machines for lighting.
II. Dynamo-Electric machines for plating.
III. Dynamo-Electric machines for miscellaneous purposes.
IV. Dynamo-Electric motors, and Transmission of energy.
V. Arc lamps.
VI. Carbons for arc lamps.
VII. Incandescent lamps.
VII. Photometric measurements.
IX. Dynamo-metrical measurements.
X. Boilers.
XI. Steam-engines.
XII. Gas-engines and other prime motors.

XIII.—*Apparatus for high electro-motive force.*

1. Lightning protection. 2. Electro-static induction machines and induction coils. 3. Igniters.

XIV.— *Voltaic-electric apparatus.*

1. Voltaic batteries and accessories. 2. Polarization and storage batteries.

XV. Electro-metallurgy.
XVI. Thermo-and-magneto-electric apparatus.

XVII.—*Electric conductors.*

1. Telegraph and telephone wires and cables. 2. Electric light and power circuits. 3. Submarine cables.

XVIII. Underground conduits.

XIX.—*Electric telegraphs.*

1. Morse systems. 2. Printing telegraphs. 3. Duplex, quadruplex, multiplex and harmonic system.

XX. Telephones, microphones and radiaphones.
XXI. Fire and burglar alarms and annunciators.
XXII. Electro-signal and registering apparatus.
XXIII. Electro-therapeutic apparatus.
XXIV. Electro-dental apparatus.
XXV. Applications of electricity to musical apparatus.
XXVI. Applications of electricity to artistic effects and art productions.
XXVII. Applications of electricity to warfare.
XXVIII. Instruments of precision.
XXIX. Educational apparatus.

M. B. SNYDER, (*Chairman,*)
WM. D. MARKS,
CARL HERING,
WM. P. TATHAM,
CHAS. H. BANES,
Executive Committee of Board of Examiners.